A PRACTICE OF
THORACIC SURGERY

BY

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PREFACE

In choosing the title of this book I deliberately selected the words A Practice rather than The Practice of Thoracic Surgery A real system of thoracic surgery requires several volumes and several authors to achieve any degree of comprehensiveness In attempting to clear my views as to my own practice I have reluctantly discarded descriptions of obsolete techniques and views being only too conscious that by the time this volume appears many of these may have been revived even if in altered form for this is common in the history of surgery which is always punctuated by advances real or ill-conceived and retreats which may be wise or misguided. In many places no doubt the obvious is reiterated with sickening monotony and the difficult is ignored I have attempted to stress the points of difficulty that puzzled me when I first encountered them and to answer the questions so often put to me by physicians general practitioners or young surgeons in the course of their training whether they be studying abdominal or thoracic surgery I have failed to summarize the vast literature on thoracic surgery and many omissions are obvious In a developing field of surgery information is passed largely by word of mouth and I owe a great deal to conversations at the meetings of the Association of Thoracic Surgeons of Great Britain and Ireland I must apologize for unrecorded acknowledgements to surgeons whose opinions have frequently guided me At all events I can say that this book is not for my own colleagues in the thoracic field, for all in it is known to them but I should like to dedicate it to the members past and present of that Association and ask their indulgence for any imperfection.

The thoracic surgeon is dependent largely on the help of his colleagues and I acknowledge with gratitude the encouragement and assistance that I have received from a wide circle of physicians surgeons radiologists and pathologists There is a danger of thoracic surgery becoming segregated from Teaching Hospitals if this trend progresses such isolation will be injurious to undergraduate and post graduate clinical education as well as to thoracic surgery Professor F A. R Stammers has always arranged for its inclusion in the Department of Surgery in the University of Birmingham and I acknowledge with gratitude his constant help and influence I am especially grateful to Dr Brian Taylor who in addition to developing and encouraging the spread of thoracic surgery in this area has written the introduction and provided helpful criticisms of many sections of the book I must thank Professor Melville Arnott Professor of Medicine in the University of Birmingham for his constant advice and encouragement and his colleagues Dr K. W Donald and Dr Paul Davison for the sections respectively on Lung Function and Cardiac Catheterization also Dr Roy Astley radiologist to the Children s Hospital, Birmingham for a thorough and lucid account of Angiocardiography Mr Robert Brain a loyal colleague and friend and now on the staff of Guy s Hospital has provided invaluable assistance in many sections notably those on post-operative treatment and the nutrition of the surgical patient

I am indebted to Mr T F Dee clinical photographer to the Queen Elizabeth Hospital Birmingham for the major portion of the photographs and reproductions of radiographs which has entailed a great deal of work on his part I must also thank Mr J G Williamson A I B P A R P.S clinical photographer to the Children s Hospital Birmingham for providing the work illustrating conditions in childhood

I acknowledge with pleasure the assistance given by Mr R Schranz of the Genito-

Urinary Manufacturing Company for his kind loan of blocks to illustrate his beauti instruments which have a world-wide fame of their own

Many colleagues have generously placed their clinical material at my disposal; addition to those already mentioned I must thank Dr J E Geddes, the head of the B mingham Tuberculosis Service, Dr Clifford Parsons of the United Birmingham Hospit Dr D J. McIlveen of Hill Top Thoracic Surgical Hospital and my surgical colleag Mr S J. MacHale and Miss Ruth Richardson for much help I owe a great deal of gratitu to many surgical registrars and house officers who have provided a great stimulus to r and to many members of the nursing profession for something much more than devot service to my patients

Miss Mary Jones, M B , Ch B , a former house surgeon, has indefatigably checked a re-checked the references, and I am grateful for her untiring and painstaking efforts

My present registrar, Mr Keith Roberts, has made the index for me and I am grate to him for the hours of devoted labour he has given to this task The method of number the illustrations has been copied quite unashamedly from Dr Paul Wood's book on " Disea of the Heart and Circulation " (Eyre and Spottiswoode)

But for Miss Mary Bowers, my secretary, this book would never have reached t printers not only has she typed the manuscript, but she has provided most of the drawi presented and has laboured with the greatest energy and good humour over a difficult ta and this expression of thanks is quite inadequate

I must also acknowledge my deep gratitude to my wife for her constant encourageme while writing this book and for her unfailing and unselfish support during the toils of production

Mr Clare, of Messrs Edward Arnold & Co , has given freely of his great experien and wisdom and no author could have had a more patient, friendly and tolerant publish I can only thank him warmly

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INTRODUCTION

By A BRIAN TAYLOR MD FRCP

Physician to the United Birmingham Hospital and to the Birmingham Regional Thoracic Surgical Centre

The development of thoracic surgery during the past 30 years has been one of the most striking and exciting features of medical progress in this century—a period when progress has been fast and remarkable in many fields Chest injuries in the first world war, and the effects of the influenza pandemic after it set the stage and in this country Morriston Davies Tudor Edwards and Roberts were the leading actors to rise to the occasion From them the mantle has fallen on a modern generation which has not stood still, but has extended the field and advanced the technique that this branch of surgery offers At this moment it is wise to survey the position that has been reached and to take stock Mr d Abreu has done this in his book—both by describing the widest aspects of thoracic surgery and by critically reviewing the values of the methods and techniques from his own wide experience

Mr d Abreu is particularly well fitted for this task. He has worked with and enjoyed the intimacy of all the leading thoracic surgeons in this country His contacts in Europe and America have been numerous and frequent both during the war and in civil practice His experience in the Welsh National Memorial Tuberculosis Service in which he was fortunate to work under the kind and friendly guidance of Mr Morriston Davies and Sir Clement Price Thomas before the war in the Army throughout the whole war and in many of the most active fields and in his development of thoracic surgery in the Midlands since the war have given him exceptional experience of which he has taken the fullest advantage He therefore writes with the authority of an experienced surgeon a brilliant teacher and a keen supporter of research both practical and theoretical into all the disorders within the chest

Accompanying and making possible all these advances have been the notable extensions of the ancillary subjects and methods The physiology of cardio-respiratory function is perhaps hardly to be described as ancillary it is fundamental though it is only in recent years that it has caught up and accompanied practical therapeutics Radiology perhaps has pride of place in having brought an understanding of thoracic function and disease which the traditional methods of clinical examination could never by themselves achieve Advances in anaesthesia and particularly the closed circuit methods have enabled thoracic surgeons to embark safely on operations within the chest One must also include the help given by nursing and physiotherapy in the management of thoracic disease and the pre and post-operative treatment

It will be apparent that the thoracic surgeon is in the centre of a large team of experts—specialists in particular methods who have all advanced with him in knowledge research and technique This book amply supports this basis of the team and gives credit to the numerous members of the team The physician in the team may think of himself in several ways—as the collector and diagnostician to bring the patients to the team at the right time and in the right way as the co-ordinator of the members of the team perhaps as their controller and guide In practice he is probably the adviser and student This admirable state of affairs has been achieved in Birmingham and Mr d Abreu s thesis underlines the co-ordinated working of his team

At the Queen Elizabeth Hospital in Professor Arnott s Department of Medicine research

and practice in cardio-respiratory physiology has kept the feet on the ground The stimulus of teaching, the wide opportunities for research and research workers, and the influence of University and Hospital departments with their critical and helpful staffs, have supported the organization Fortunately, too, the closest liaison has been reached with the development of thoracic surgery under the Birmingham Regional Hospital Board, who have recently opened a special hospital for thoracic surgery In the last analysis, the help given to the patients with thoracic disease is the criterion of the success of the method, and with this effective organization now in its stride one can watch this with confidence

PART I

ANATOMICAL AND PHYSIOLOGICAL CONSIDERATIONS

INTRODUCTION

A surgeon entering into a new field of surgery has the privilege and advantage of starting at a point already reached by his masters and teachers In 1934 largely through the kind encouragement of the late Professor Lyle Cummins the Professor of Tuberculosis in the University of Wales I started the study and practice of thoracic surgery Conversations with colleagues convince me that many members of our profession believe that thoracic surgery is of recent origin an error that is corrected if the original work of the pioneers is studied In 1934 a wide literature was available and an account of the surgery of the chest up to that date would fill a large volume Assuming that much of that knowledge has become part and parcel of the modern practice of surgery I have attempted in this book to outline the present position of a subject that continues to advance in a most exciting way in the physiological as well as the technical field After much strenuous work by pioneers such as Sauerbruch Lilienthal Alexander Morriston Davies Roux Murphy Tudor Edwards J E H Roberts and a host of others a rational treatment had evolved for the care of empyema and certain forms of chronic pulmonary tuberculosis Shenstone and Janes (1932) had developed a one-stage technique for lobectomy in bronchiectasis and the tourniquet form of that operation now abandoned had given an enormous impetus to surgery Total pneumonectomy for bronchiectasis and for neoplasms of the lung developed rapidly greatly helped by notable improvements in thoracic anaesthesia and in the readier application of blood transfusion Operations across a free pleura became commonplace The outbreak of war in 1939 found the newer surgical techniques ready to be applied to the war wounds of the chest a better understanding of the physiological disorders of the wounded chest and later the availability of the new antibiotics enabled thousands of chest casualties to make full recoveries The lessons learnt in the conflict were applied coincidentally to other thoracic diseases and in spite of the confusion of the days thoracic surgery made great progress Those of us who were engaged solely in military surgery were astonished but none the less delighted to find that a host of new techniques had to be learnt on returning to civilian surgery In resection of lung tissue the addition of dissection lobectomy to the already established method of individual ligation of the great hilar structures for the eradication of malignant disease of the lung represented the greatest advance for it could be applied to the common diseases of pulmonary tuberculosis bronchiectasis and chronic lung abscess Its superiority over the older cumbrous and unsafe method of tourniquet lobectomy was obvious The logical extension of this type of resection operation was the development of safe methods for the removal of segments and subsegments of the lung when these were the seat of isolated eradicable disease The coincident improvements in anaesthesia and in the pre and post-operative phases were such that published series of resection for bronchiectasis often reported a mortality rate of under one per cent

The application of thoracic surgery to the treatment of lung cancer, pulmonary tuberculosis, bronchiectasis and chronic lung abscess was no longer limited by hesitancy on the part of physicians to refer patients in a way that was noticeable before the war, but by the lack of thoracic surgeons and anaesthetists and by the poverty of institutional provision for the care of such patients

The oesophagus had ceased to be regarded as a deeply placed, unapproachable organ and new chapters had been written on the management of its neoplastic disease and in the detection and relief of non-malignant lesions such as oesophagitis, peptic ulceration, cardiospasm and diverticular formation The free incision of the diaphragm by the thoraco-laparotomy incision of the military surgeon for the treatment of many thoraco-abdominal wounds found an equally favoured civilian use for the approach to carcinoma of the stomach, for portal hypertension and for splenectomy , it was rapidly employed in a modified form for certain methods of performing thoraco-lumbar sympathectomy for hypertension

The ligation of the patent ductus arteriosus, the resection of the coarcted aorta and the whole new field of surgical attempts to relieve the disordered physiology of congenital heart disease so brilliantly exampled by Taussig and Blalock greatly widened the horizon of both physician and surgeon and accentuated the need for co-operation between them The thoracic surgeon is now concerned with the treatment of pathological and disordered physiological states of the cardio-vascular, respiratory, alimentary and neurological systems , he must therefore be a general surgeon working in a wide region , he must be able to examine endoscopically the larynx, trachea, bronchus and oesophagus , thoracoscopy is daily used in the control and help of artificial pneumothorax and for the diagnosis of certain lung and mediastinal lesions The recognized surgical approaches may include the exploration of the neck and abdomen as well as of the thorax , splenectomy or thyroidectomy may be done as individual operations or as part of more extended procedures such as total gastrectomy for cancer or the excision of malignant growths of the upper end of the oesophagus

The pre-war tendency to separate the surgery of pulmonary tuberculosis from that of other thoracic disease has receded with the increased adoption of resection operations in the treatment of pulmonary tuberculosis, and this has emphasized the similarity of techniques required in the management of both groups of diseases

The general principles of surgery naturally govern the practice of chest surgery and the thoracic surgeon must have had an adequate post-graduate training in general surgery before concentrating on this work , the application of recent advances in chemotherapy, resuscitation, the maintenance of correct fluid and electrolyte balances, and physiotherapy, are adopted vigorously in major thoracic surgery, and the meagre reference to them in this book implies that the readers have an understanding of them and is because they are not peculiar to this branch of surgery In recent years surgical techniques and aims have become more physiological and the particular position of thoracic physiology requires a more lengthy exposition than the anatomical and pathological accounts presented The advances in thoracic physiology have been too extensive to allow an adequate account of them to be presented and only an outline of that fascinating adventure can be given

Through empirical trial and error and with the support of the anaesthetist, at least a working knowledge of the physiology of the open pneumothorax has been achieved, but only in recent days have the scientific approaches of the physician engaged in the study of human respiratory physiology been applied to our craft , centuries of perplexing errors and fears in the management of wounds of the thorax have led at last to a simple solution of the treatment of the sucking open wound and infection of the pleural cavity , in the recent conflict, the application of physiological knowledge insisted on the early closure of the sucking wound,

and after that excision of the damaged area of the thoracic pariotes which surgical experience has shown to be the essential prophylaxis against crippling infection but the story did not end there and the insistent demand of physiological principles called for early resort to methods that would improve lung function hence the early aspiration of traumatic effusions the decortication of the strangled lung the use of physiotherapy the warding off of anoxia by rational oxygen therapy and the use of blood transfusion, all measures designed to correct a disorganized physiology The technical advances in lung or lobe excision in the treatment of pulmonary tuberculosis and cancer and in the surgical endeavours to improve the function of the physiologically and anatomically deformed or diseased heart are not enough

Surgeons who stand on the threshold of the surgery of the lung today will not find prestige and fame in treading the easy pathways that were open to the older members of this Association We enjoyed for a brief period the heyday of rapid technical development that follows the initial conquest of a new territory Advance in the surgery of the lung will not be derived from technical experience alone (Churchill 1949)

My own shortcomings in physiological knowledge are fortunate in the respect that Professor Melville Arnott s colleagues Dr Davison and Dr Donald have consented to write on Physiological Considerations in this book

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CHAPTER 1

ANATOMICAL CONSIDERATIONS

Accurate diagnosis and the execution of safe surgical techniques depend largely on the unravelling of distorted anatomy in the thorax the anatomical picture presented at thoracotomy for the removal of a lung with an early carcinoma differs vastly from that seen when extreme pleural and pulmonary disease has apparently destroyed all anatomical planes and dispositions as in chronic empyema, advanced bronchiectasis or tuberculosis But the dissection of planes through organized fibrous tissue ultimately displays an anatomy of remarkable regularity and nowhere is this more noticeable than in the deliberate exposure of the vessels and bronchi of a lung, lobe or segment preparatory to its resection But notable abnormalities do present these provide the basis for the attempted correction by surgery of congenital abnormalities of the heart and the confusing pictures that may be present have been noted in the careful operative studies of Blalock (1948)

Precise diagnosis and localization of many lesions will be impossible if age-long anatomical accounts are accepted in their entirety Illustrating the newer conceptions may be quoted the exact verbal and pictorial descriptions of bronchial anatomy provided by Brock (1946), and the recent attempt to obtain international acceptance of a universally recognized nomenclature for the various broncho-pulmonary segments (*Thorax*, 1950) False ideas on facts so fundamental as the location of the great fissures of the lung have only slowly been abandoned The great oblique fissure of the lungs, formerly considered to start posteriorly at the level of the fourth rib or the third thoracic spinous process, is actually at a much lower level, usually that of the fifth or sixth rib, a piece of knowledge vital to those dealing with an abscess or tuberculous cavity of the apical segment of the lower lobe for radiological localization, and certain surgical attacks will depend on the simple counting of ribs in relation to the underlying cavity

THE ANATOMY OF THE LUNG

Although most lungs show a clear division by definite fissures between the lobes, such lines of cleavage may be obliterated in whole or part by well-defined bridges or by inflammatory adhesion of lung tissue , areas of true fusion are seen best between the apex of the lower lobe and the posterior segment of the upper lobe and between the upper and right middle lobes In surgical resections of lobes or segments this continuity of lung parenchyma between one lobe and another may hamper the dissection and exposure of hilar vessels, but once the vessels and the appropriate bronchi (lobar or segmental) have been isolated and divided the segments of lung to be removed can be peeled out along the relatively avascular segmental or lobar boundaries If the lung is kept fully ventilated by the anaesthetist after the bronchus of the area to be removed has been clamped and divided, the line of demarcation between the aerated and non-aerated areas will be obvious unless pathological air drift is present (see p 10) In such operative dissections the segmental vein is an excellent guide to the excision as it follows the line of the boundary between the segment to be removed and its neighbour

The bronchial and vascular supply to the main lobes

The different anatomical arrangements of the two lungs have surgical significances in general pneumonectomy is technically easier on the left side than on the right because of the greater length of the vessels and main bronchus and because the superior vena cava partly overlies the right main pulmonary artery on the other hand the removal of the right upper lobe is simpler than that of the left where the arterial supply is arranged more awkwardly from a surgical point of view because of the sweep of the left main pulmonary artery behind its bronchus These apparent anatomical difficulties are however readily overcome in both instances if dissection of the perivascular sheath is thorough and adequate



Fig 1 1



Fig 1 2

Fig 1 1—Lateral radiograph of a child.
The interlobar fissures show up well after a previous pleurisy Note especially the posterior projection of the great fissure

Fig 1 2—Segmental collapses due to infected muco-pus.
Bronchoscopy was negative for neoplasm and the segments rapidly re-expanded. The areas collapsed are the apex of the right lower lobe and the anterior and posterior segments of the right upper lobe Note the position of the apex of the lower lobe

The bronchial supply

(*A*) *The left side* The main stem bronchus from the carina of the trachea to the upper lobe orifice is much longer and has a more oblique course than the right sided one The upper lobe bronchus leaves the outer side of the main stem and divides into the lingula the apical the posterior and the anterior segmental bronchi sometimes the apical and posterior bronchi have a common stem and this has led to the description of an apico posterior segment in some works The left intermediate bronchus is that portion of the main bronchus between the origin of the upper lobe bronchus and the branches to the lower lobe and is extremely short because the apical segmental bronchus is not much below the

level of origin of the lingular bronchus when exposed in the main fissure as in the operation of left lower lobectomy and lingulectomy The subdivisions of the bronchus into segmental branches is considered later

(*B*) *The right side* The right main stem bronchus leaves the carina more vertically than the left one and is wider and shorter. The upper lobe bronchus leaves it at a distance less than 2 cm from the trachea, is more horizontal in direction than the corresponding bronchus of the left upper lobe and lies at a higher level than the main pulmonary artery, hence its older description, now discarded, as the eparterial bronchus As the bronchus descends it is covered in part by the main stem of the pulmonary artery which is partially covered anteriorly by the superior pulmonary vein The middle lobe bronchus arises from the anterolateral surface of the main stem and is usually opposite the bronchial opening of the apical segment of the right lower lobe as that leaves the posterolateral surface of the main bronchus The main bronchus then passes on to divide into the four segmental bronchi of the lower lobe

THE NOMENCLATURE OF THE BRONCHO-PULMONARY SEGMENTS

Various authors in presenting their individual accounts often gave different names to the segments, so that a confused nomenclature evolved A recent attempt at an internationally accepted classification was reported to the Thoracic Society of Great Britain (1950) and this nomenclature will be adopted here As it displaces many commonly accepted terms some of these will be given in brackets

The Right Lung

The three lobes of this side have ten main segments distributed as follows

(*A*) *The right upper lobe*

1 Apical segment
2 Anterior segment (Anterolateral or pectoral)
3 Posterior segment (Posterolateral)

(*B*) *The middle lobe*

4 Medial segment (Superior)
5 Lateral segment (Inferior)

(*C*) *The right lower lobe*

6 Apical segment (Dorsal lobe, superior segment)
7 Medial basal segment (the cardiac lobe)
8 Anterior basal segment
9 Lateral basal segment (Mid-basal segment)
10 Posterior basal segment

(These are "major" segments subdivisions occur of which perhaps the most commonly described is the sub-apical segment of the apical division of the lower lobe)

The Left Lung

This has nine main segments

(*A*) *The left upper lobe*

Upper division i e that portion of the lobe bronchus before the lingular bronchus has left it has three segments

1 Apical segment } (Apico posterior bronchus)
2 Posterior segment }
3 Anterior segment (Anterolateral or pectoral)

(*B*) *The lingula* (Lower division bronchus)

4 Superior segment
5 Inferior segment

(*C*) *The left lower lobe*

6 Apical segment
7 (Absent when compared with right side i e no cardiac lobe)
8 Anterior basal segment
9 Lateral basal segment (Mid basal segment)
10 Posterior basal segment

The chief alterations in this nomenclature are that the terms medial and lateral are preferred to 'internal and external that the use of axillary has been abandoned and that dorsal lobe is no longer used as descriptive of the upper segment of the lower lobe No classification is likely to please everyone and the one quoted fails to indicate certain other segments that are at times additionally present but it has certain merits of simplicity and is of value to the clinician

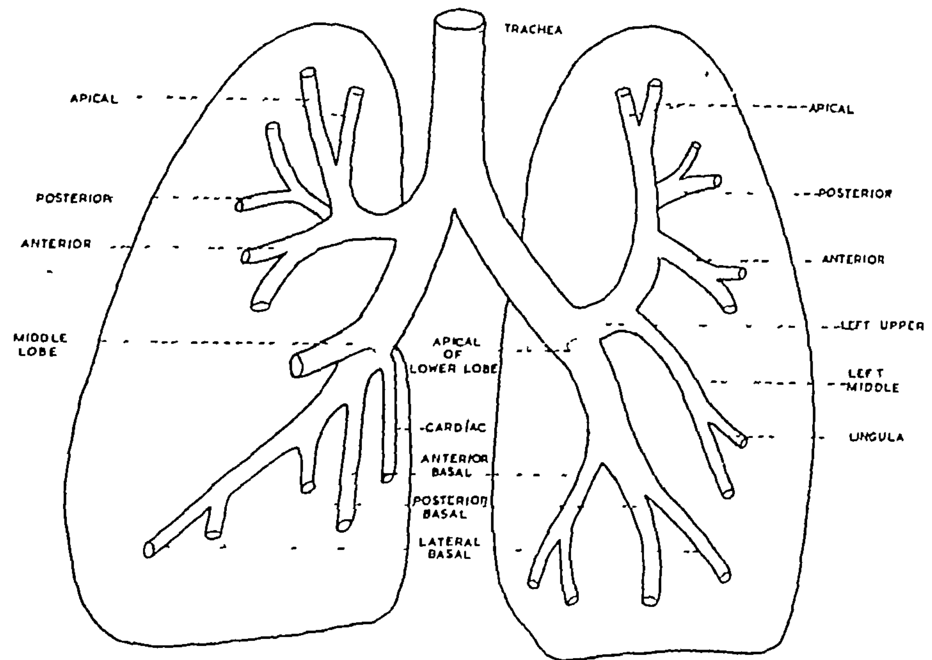
Anatomy of the broncho-pulmonary segment

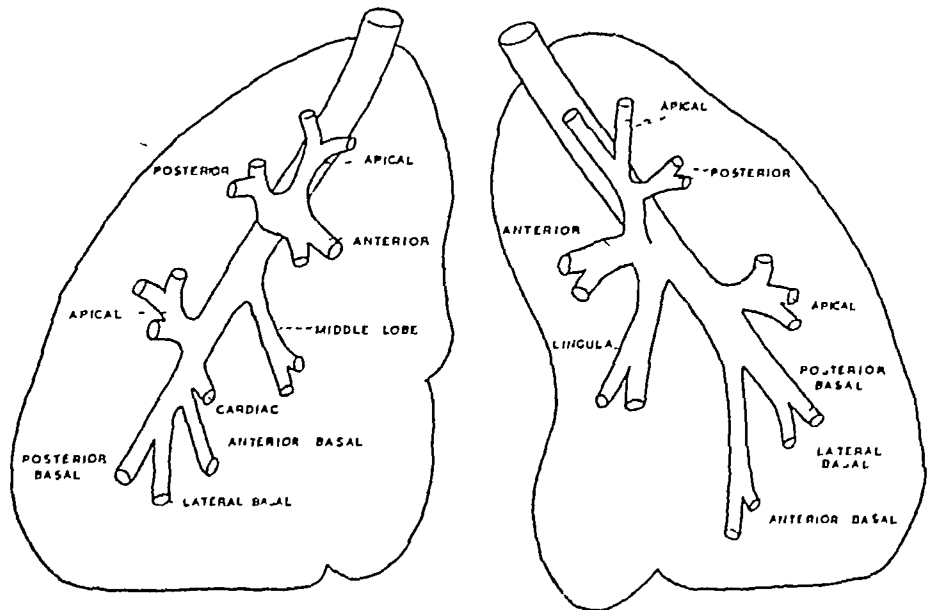
The stimulus given to the development of better techniques for the removal of diseased lobes by the careful anatomical expositions of workers such as Brian Blades and Kent (1940 1942 and 1943) was followed by many clear publications on the anatomy of the hila of each individual segment and the surgical removal of isolated diseased segments became an established procedure This conservative resection first practised on the lingula segment of the left upper lobe (Churchill and Belsey 1939) was soon adopted in the treatment of bronchiectasis confined to certain segments of a diseased lung so that unisegmental or multisegmental excisions avoided the unnecessary sacrifice of healthy lung tissue a conservatism of especial value when the disease is bilateral (Pilcher 1941 Overholt 1948)

Each segment has a fairly constant anatomical arrangement of its bronchus and artery but the veins and lymphatics have frequent communications with those of the adjacent lung areas

Intersegmental veins

Because of the important influence these have on the technique of segmental resection a special account of their anatomy is necessary Boyden and Scannell (1948) described clearly the existence of these veins in addition to each individual segment having a clearly defined vein blood passes to another vein that lies in the plane between two adjacent segments If this vessel is ligated during a segmental resection the venous return of the healthy adjacent unit is largely obstructed so that passive congestion follows and this may be sufficient to produce post-operative haemoptysis It is not always easy to define the trunk of this intersegmental vein at the hilum and in the actual operation it is wiser whenever possible to divide the artery and bronchus apply gentle traction to them and so open up





(*a*)

Fig 1 3

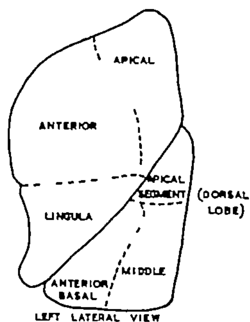
(*a*) Diagrammatic representation of the bronchi the upper drawing represents the anterior view, the lower diagram illustrates the lateral aspects

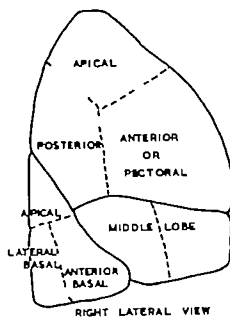
(*b*) Shows the segments of the left lung as seen from the lateral and mediastinal aspects

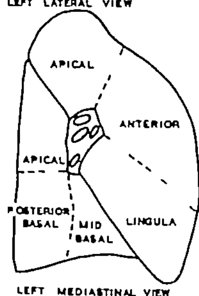
(*c*) Segments of the right lung as seen from the lateral and mediastinal aspects

(*d*) Segments of the right and left lungs seen from the anterior aspect

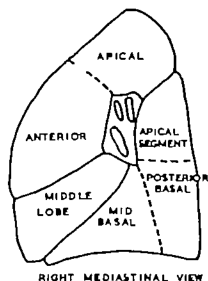
Note In Figs 1 3 (*b*), (*c*), (*d*), "Mid Basal" should read "Lateral Basal"


APICAL
ANTERIOR
APICAL SEGMENT
(DORSAL LOBE)
LINGULA
MIDDLE
ANTERIOR BASAL
LEFT LATERAL VIEW

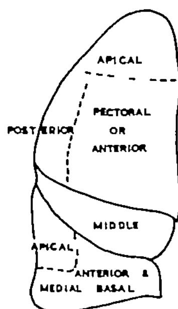

APICAL
POSTERIOR
ANTERIOR OR PECTORAL
APICAL
MIDDLE LOBE
LATERAL BASAL
ANTERIOR BASAL
RIGHT LATERAL VIEW


APICAL
ANTERIOR
APICAL
POSTERIOR BASAL
MID BASAL
LINGULA
LEFT MEDIASTINAL VIEW

(b)


APICAL
ANTERIOR
APICAL SEGMENT
POSTERIOR BASAL
MIDDLE LOBE
MID BASAL
RIGHT MEDIASTINAL VIEW

(c)


APICAL
PECTORAL OR ANTERIOR
POSTERIOR
MIDDLE
APICAL
ANTERIOR & MEDIAL BASAL


APICAL
ANTERIOR
LINGULA
AN TERIOR & MEDIAL BASAL

(d)

the intersegmental plane As the plane is defined by a combination of traction, blun gentle scissor dissection, both the segmental and intersegmental veins become obvic the field is kept clear of blood At this stage the segmental vein can be isolated, dr and ligated and any small branches to the intersegmental vessel divided so that its trunk is left patent (Chamberlain and Ryan, 1950) If the segmental artery and bron are isolated and divided, traction away from the hilum enables the particular segme be peeled out of the surrounding lung tissue During this separation the main segm vein is seen emerging from the area to be resected and after its ligation and divisio segment can be drawn out until it is held only by a covering of visceral pleura wh readily divided to allow complete removal The raw areas of the contiguous lung t bleed a little from the rupture of small communications with the intersegmental veins if there is a positive intrabronchial pressure, air and anaesthetic gases will bubble o damaged alveoli for a little while, but since there is no intersegmental communicati bronchi this soon ceases

Air drift

The extended use of lobar and segmental resections has demonstrated with cert that in conditions of disease, at all events, collateral ventilation can take place from to lobe or segment to segment independently of the bronchial route From time to when bridges of lung tissue connect one lobe to another, as so frequently happens, a po of the lobe to be resected can be filled with air if the anaesthetist increases the pressu gases in the bronchial tree *after* the bronchus of the lobe has been isolated, clamped divided Churchill's observations (1949) support the claim of van Allen and Lindskog collateral ventilation can take place between adjacent broncho-pulmonary segments drift of air from alveoli of one segment to another probably takes place only when entra air is present as a result of partial obliteration of the bronchioles producing emphy and as a mechanism adapted to deal with abnormally high intra-alveolar tensions, ar fulfil a space-occupying function

DETAILS OF SOME SEGMENTAL "HILA"

The lingula segment

This segment is the commonest one to be resected, usually in combination with a lower lobectomy for bronchiectasis in about 60–80 per cent of examples of bronchiect of the left lower lobe the lingula is also involved The bronchus to the segment usu leaves the lower surface of the left upper lobe bronchus about 1 5 cm from its commencen but this is highly variable as often demonstrated by a pre-operative study of the bron gram It may proceed in a direct line from the main bronchus and exceptionally from anterior basic bronchus Rarely the bronchus may be a separate stem of the main bronc

The artery arises from the anterior surface of the main pulmonary artery belo branch or branches to the anterior segment of the upper lobe and on a slightly higher le or opposite to the origin of the posterolaterally directed vessel proceeding to the ap segment of the left lower lobe The lingular artery lies lateral to the segmental bronc which is exposed after the vessel has been ligated and divided The vein lies anteromedi to the bronchus and drains into the superior pulmonary vein

apical segment of the lower lobe (dorsal lobe)

Resection of this segment may be indicated in the treatment of a tuberculous cavity or bronchiectasis confined to it, it may be spared when the remainder of the lower lobe being sacrificed for bronchiectasis restricted to the basal segments

If the fissure between the upper and lower lobes is exposed by dissection and adequate retraction the main pulmonary artery will be seen pulsating in its sheath free opening the sheath exposes the vessel and its first branch to the lower lobe passes backwards and upwards from the posterior surface of the main stem segment lying anterior to the

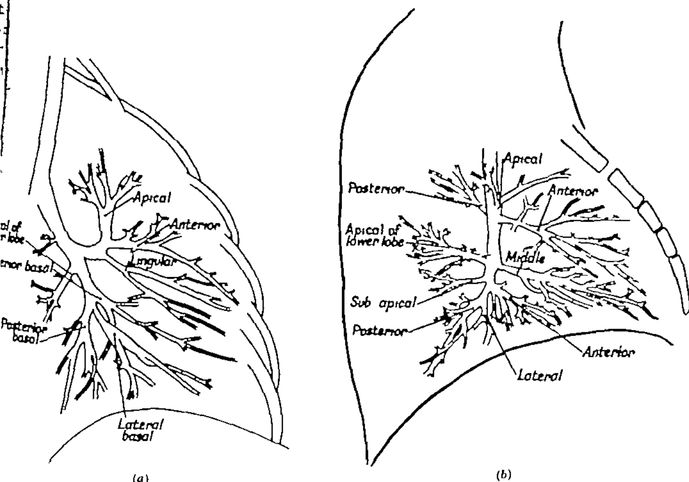


Fig 1 4

(a) Diagram of bronchogram of left lung (right oblique view).

(b) Diagram of bronchogram of right lung (lateral view)

segment bronchus If the lower lobe is retracted medially and the pleura divided in front of its reflection on to the aorta the segmental vein will be seen lying in a plane posterior to and below the bronchus of the segment before it joins the inferior pulmonary vein

The lower lobe segments

The arteries to these segments (four on the right three on the left) are displayed in the main fissure as they branch off from the main stem below the points of origin of the middle lobe vessel on the right and lingular artery on the left and of the superior segmental arteries to the lower lobe All these arteries lie anterior to the bronchial divisions from which they are separated by thick connective tissue their draining veins join to form the posteriorly placed inferior pulmonary vein

The apical segment of the upper lobe

The artery to this segment is the first branch of the pulmonary artery, if the below the azygos vein on the right or the aortic arch on the left is incised and the the lung depressed downwards, the artery is seen anterior to the medial edge of th bronchus The segmental vein lies anteriorly and crosses the main downward contin of the pulmonary artery before entering the principal superior pulmonary vein, a segment can be resected without any exposure of the major fissure of the lung, as the lobe bronchus is well displayed as soon as the segmental artery and vein have been and divided

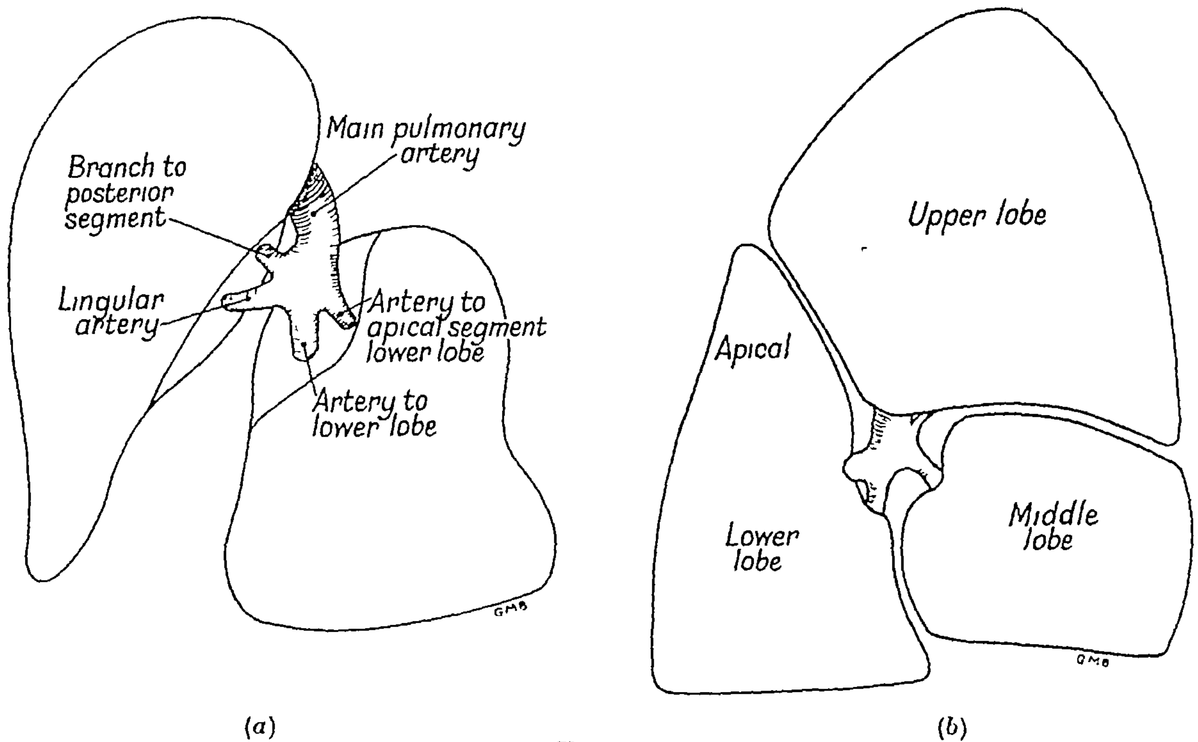


Fig 1 5

(a) Diagram of lingular artery and other arteries of left side

(b) Diagram to show right pulmonary artery As seen in the main fissure

The anterior (pectoral) segments of the upper lobe

(a) *On the right side* The artery to the segment arises from the main pulmonary distal to the vessel supplying the apical segment and lies anteromedial to its bronchu vein being placed more anteriorly to drain into the upper division of the pulmonary A little dissection of lung parenchyma is required, before the rather deeply placed segm bronchus can be exposed

(b) *On the left side* The artery to this segment leaves the anterior surface of th main pulmonary artery after it has curved behind the left main bronchus and mu exposed near the top of the great fissure after the sheath enclosing the main vess been opened frequently there are several branches

The posterior segments of the upper lobes

This segment, on the right side especially, is a common site for tuberculous cavit and for lung abscess because the common practice of sleeping in the right lateral pos renders this area peculiarly liable to bronchial embolism

As it lies posteriorly and laterally it is in contact with the apex of the lower lobe to which it is often partially fused quite apart from pathological process In resection for upper lobe tuberculosis it is frequently noted that disease has spread across the fissure to invade the apical segment of the lower lobe

The segmental artery lies deeply it leaves the main arterial stem as it lies close to the main bronchus and slightly above the level of origin of the middle lobe artery and the vessel to the superior lower lobe segment It can only be secured when the fissures between the upper middle and lower lobe (on the right) have been freely dissected and the pulmonary artery deep in the fissure has been clearly dissected free of its sheath so that the anterior segmental artery the middle lobe artery and that going to the apex of the lower lobe have been fully displayed In upper lobectomy for tuberculosis it is important to see this vessel clearly before the lobe is removed for occasionally it arises from the artery to the apex of the lower lobe and that vessel may be damaged accidentally unless full precautions are taken to identify both structures carefully

THE VASCULAR SUPPLY TO THE LUNGS

The pulmonary arteries

Apart from important congenital cardiac abnormalities the course and disposition of these vessels are remarkably constant The fibrous pericardium extends widely over both pulmonary arterial trunks though the main stems are extrapericardial especially on their inferior aspect are they in close contact with serous extensions of the pericardial sac On both sides a serous extension of the pericardial sac lies between the pulmonary artery and the superior pulmonary vein the vestigial fold consisting of the obliterated vein of Marshall lying between the two on the left side This forms a consistently stout fibrous band when isolated at operation These extensions of the sac are of importance in the operation of dissection pneumonectomy or when the pulmonary artery is being cleared as a stage of the Blalock operation in congenital cyanotic heart disease if the pulmonary artery is being dissected clear preparatory to its encirclement ligation or temporary occlusion difficulties may be encountered if the vessel distal to the line of these extensions has not been meticulously cleared of all adventitious tissue A clumsy attempt to clear the posterior wall of the vessel may damage the pericardial extensions this is of little moment but the vessel itself or the superior pulmonary vein may be damaged if the dissection is outside the true space within the sheath On the right side there is always a strong band of fibrous tissue extending laterally from the pericardium which should be divided before the approach to the pulmonary artery is safe In the operation of intrapericardial ligation of vessels for carcinoma of the lung these folds which have been fully described by Allison (1946) are of great importance

The right pulmonary artery appears to be much shorter than the left because it is overlapped by the bulging superior vena cava but if the latter is gently retracted medially after division of the mediastinal pleura there is no difficulty in obtaining a good length for ligation and division

After the right pulmonary artery has emerged from beneath the superior vena cava it gives off its large branch to the right upper lobe The main trunk then passes beneath the superior pulmonary vein which may so overlie it that its ligation and division may be necessary in the course of a right pneumonectomy before the artery can be secured safely

a free division of the pericardial fold lying between the artery and vein makes the ligation of the vein safe and simple The arterial stem then passes on to the lower lobe where it lies immediately over the bronchus As it enters the hilum of the lower lobe it gives off a branch anteriorly to the middle lobe and one posteriorly to the posterior segment of the lower lobe In this area large lymphatic glands are present, particularly above the vessel when they are hypertrophied as the cause or result of bronchiectasis in the middle or lower lobes

On the left side the main part of the pulmonary artery curves down to the lower lobe behind the upper lobe bronchus and in that position gives off from three to six branches to the left upper lobe These branches of the artery must be continually in mind during the operation of left upper lobectomy The vessels are readily visualized if the pleura

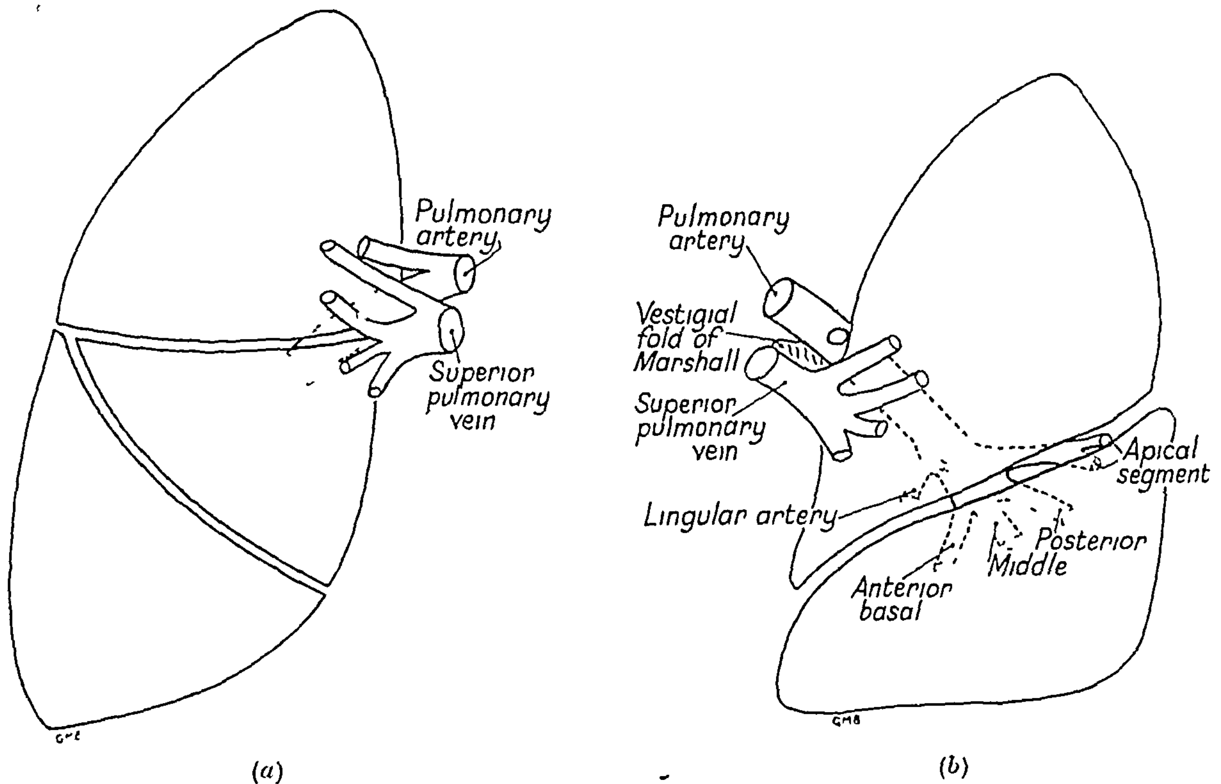


FIG 1 6

(*a*) Diagram showing relation of superior vein to right pulmonary artery
(*b*) Diagram showing relation of left pulmonary artery to superior pulmonary vein

between the aorta and the pulmonary arteries in the area of the obliterated patent ductus arteriosus is opened freely and the apex of the lobe is held downwards and medially so that the vessels mentioned can be seen and secured as they leave the parent stem

As the artery proceeds from the lung hilum to the lower lobes in the main fissure it is anterior and slightly above the bronchus which has the vein as a posterior relation The same relationship usually persists in the broncho-pulmonary segments of the lobes

Abnormalities of the pulmonary arteries The ... it abnormalities of these arteries are noteworthy particularly in congenital heart d... n one or both sides the main pulmonary artery may be al... diminutive si... sis may be present at the level of the infundibulum of ... ulmonary ste... actual valvular area; information on these points may b... by studying ... btained from cardiac catheterization and angiocardiogra... , 348) W... nar ... is absent

a partial functioning of the lung may be possible through a small blood flow caused by greatly hypertrophied bronchial arteries

In transposition of the great vessels the pulmonary artery arises from the left ventricles (in the tetralogy of Fallot the mouth of the aortic stem overrides the right and left ventricles)

Very rarely a pulmonary artery arises from a systemic vessel usually the innominate artery though exceptionally from the lower thoracic aorta the arterial supply of dissociated lung tissue (accessory cystic lobe) by a systemic artery arising usually from the abdominal aorta will be described later (p 23) Such dissociated lungs are probably examples of reduplication of the foregut and this may well explain the ectopic blood supply Certain other abnormalities of pulmonary blood supply from the aorta may be capable of embryological explanation in connection with faults at different stages in the history of the six pairs of aortic arches (Brown 1950)

To the thoracic surgeon abnormal distributions of the pulmonary arterial branches to the hila of the various segments may cause technical difficulties Perhaps the most important because of the frequent use of the operation of lingulectomy for bronchiectasis is that the lingular artery may give off a considerable branch or branches to the left lower lobe on the right side the main branch to the middle lobe may provide an artery to the inferior surface of the anterior segment of the right upper lobes The blood supply to the right upper lobe is usually on a simpler plan than that to the left upper lobe but sometimes there are more than three main branches and these should be looked for when the final stages of the detachment of the lobe towards the end of its resection have brought the dissection into the main fissure as careless pulling on these additional vessels may produce a tear of the main stem before it has entered the lower lobe

The thoracic veins

As elsewhere the pattern of veins is not so constant as that of the arteries This is not surprising when the embryological development of the complicated venous plexus that surrounds the primitive foregut and heart tube is considered Since the original sinus venosus into which many of these embryonic veins drain becomes the left auricle the pulmonary veins may be grossly abnormal and aberrant because these radicles ultimately become the anterior and posterior cardinal veins the upper of which forms the pulmonary veins while the lower takes part in the development of the inferior vena cava Not unexpectedly therefore anomalous pulmonary veins may drain into the superior vena cava the innominate veins or the right auricle (into which all or some of the pulmonary veins may drain) or the superior vena cava may be duplicated If all the veins do drain into the right auricle life would only be compatible with continued patency of the foramen ovale during the operation of right pneumonectomy a pulmonary vein is found occasionally to drain into the superior vena cava and when there is a left superior vena cava one or more pulmonary veins may empty into it Normally the left superior vena cava is obliterated and forms the dense fibrous tissue that lies between the left pulmonary artery and the left superior pulmonary veins (the vestigial fold of Marshall) the free division of which is essential in the process of isolating these vessels during the operation of pneumonectomy Rarely there may be a communication between the pulmonary veins and the inferior vena cava the joining branch passing through the diaphragm to enter the large vessel in the abdomen

The effects of abnormal venous drainage on the heart When the heart and lungs are normal a pulmonary venous drainage of less than 50 per cent of the lung blood flow into the systemic venous system probably does not lead to cardiac decompensation

but the effects of anomalous venous shunts of less than this may have serious effects when the heart is diseased or when pulmonary lesions develop in that area of the lung that previously functioned normally and when its blood drained into the left auricle Brantigan (1947) contends that if at operation for disease of one lobe requiring lobectomy the surgeon discovers that the venous drainage of the healthy lobe which it was hoped to conserve is into the major venous systemic circulation, e g a superior vein draining into the superior vena cava or the innominate vein, this lobe also should be sacrificed in order to diminish the burden on the heart

Although venous abnormalities are met with most commonly in examples of congenital heart disease, they are of importance in diagnosis and treatment of other thoracic conditions and there is evidence that pathological processes have a relative higher incidence when they exist

During lung resection operations, the veins both outside and within the pericardial sac may be abnormal On the right the middle lobe vein not infrequently enters the pericardium as a separate vessel which may join the superior pulmonary vein or proceed as a separate vessel into the left auricle The union of the superior and inferior pulmonary veins into a single trunk composed largely of atrial tissue may provide a puzzling appearance during the operation of intrapericardial dissection pneumonectomy Very rarely there may be one single major vein leading out of a lung and the recognition of such an abnormality in the course of a proposed lobectomy or segmental resection is of obvious significance

The azygos vein

This anatomical landmark during operations such as right pneumonectomy, or exposure of the oesophagus at this level, may require ligation and division to enable the hilum of the lung or the gullet to be fully displayed. It may so run that it divides up a portion of the right upper lobe as it indents the lung tissue on its way to join the superior vena cava and so gives rise to an "azygos" lobe The radiological appearances of this abnormality are typical (see Fig 1 7)

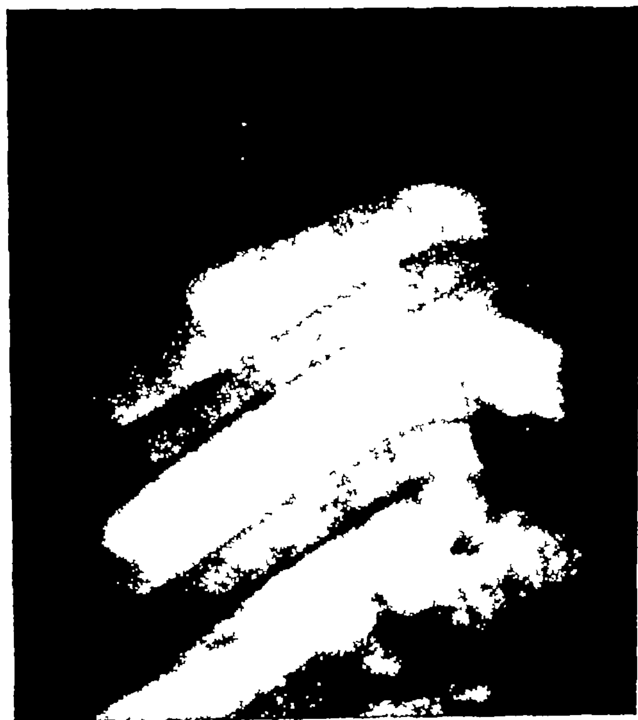


Fig 1 7 Radiograph of azygos lobe

The normal relationship of the great veins does not require detailed description, but surgically the necessity for an exact knowledge of their location is obvious On the right side the superior pulmonary vein so overlies the main trunk of the right pulmonary artery after it has given off its apical branch to the upper lobe that ligation and division may be required before the artery can be cleared and secured The inferior pulmonary vein lies posterior and inferior to the plane of the lower lobe bronchus when the lobe is displaced towards the mid-line it is separated from the bronchus to the lower lobe by a notable collection of areolar tissue, the vein is made up of four large tributaries The upper tributary drains the apical segment of the lower lobe (dorsal lobe) and as this branch lies posterior to the main lobar bronchus as it passes on to the basal

segments it must be carefully isolated and protected when the superior segment is being conserved during operation for the removal of the basal segments in bronchiectasis

THE PLEURA

A precise knowledge of the dispositions of the pleura is essential especially for the diagnosis and treatment of pleural empyema pulmonary tuberculosis and subphrenic abscess The supra-clavicular extension of the dome of the pleura is of practical importance in the modern type of upper thoracoplasty with Semb s extrafascial apicolysis (see p 215) The hypertrophy of the fibrous bands and extensions from the scalene muscle group and from the longus colli muscle that accompanies the thickening of the endothoracic fascia overlying the dome is followed by a constantly increasing traction on this altered Sibson s

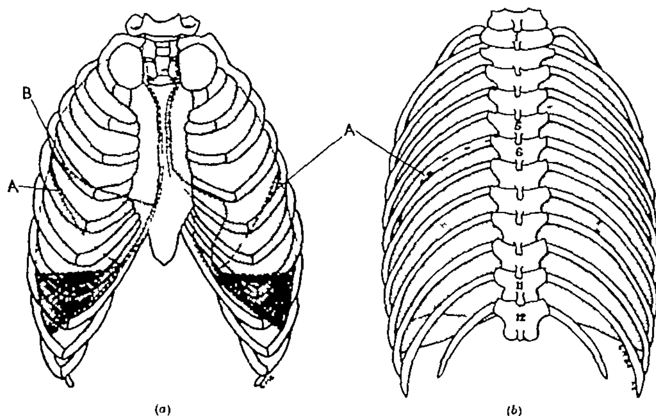


Fig 18

(*a*) Diagram of the pleural disposition as seen antero-posteriorly
A indicates the site of the great oblique fissure in relation to the ribs B the transverse fissure on the right. The deeply shaded area indicates the position of the lung in *inspiration*.

(*b*) Diagram to indicate the pleural disposition seen from the posterior aspect
The great oblique fissure has only been indicated on the left side

fascia Apical cavities underlying such pathologically altered attachments may fail to close unless they are freely divided

The normally thin fibro-elastic pleura is attached to the endothoracic fascia differently in the various parts of the thorax Over the apex and mediastinum the *pleura can* be separated readily in this plane this separation is not so easily achieved laterally or anteriorly where the attachment is firmer but the firmest attachment of the parietal pleura is to the dome of the diaphragm and when it is pathologically thickened the attempt to dissect it

free is difficult This fact plays a rôle of importance in the treatment of subphrenic abscess and the hope that transthoracic drainage without pleural transgression may be possible is indeed a flimsy one and not to be relied upon in practice (see p 571)

By a mixture of blunt and sharp dissection the pleura can be separated through the plane of loose areolar tissue in the endothoracic fascial plane in the mediastinum both anteriorly (as when the sternum is split for the removal of the thymus or some examples of retro-sternal goitre) and posteriorly in the exposure of the oesophagus (e g in the repair of congenital oesophago-tracheal fistula) In practice the dissection of the parietal pleura is usually carried out during the course of a wide transpleural thoracotomy and its free division in the exposure of the pulmonary vessels, of the patent ductus arteriosus and the oesophagus is a commonplace, and the ease with which it can be freed is noteworthy

When thickened by disease the vascularity of the pleura and of its attachments is increased This has an importance in such operations as pleuro-pneumonectomy when the whole pleural sac together with the lung is removed along a line of dissection that proceeds in the plane of the endothoracic fascia (p 257), or in the operation of extrapleural artificial pneumothorax (p 223)

In surgery the pleura carries all the advantages and disadvantages of the peritoneal membrane It has strong powers of repair and can deal with infections that are transient and not due to a continuous leak from intrathoracic organs such as the lung or oesophagus , it readily forms adhesions that may be protective but also destructive of normal physiological process , its gross thickening over the lung or chest wall seriously impairs the normal respiratory physiology, strangling the impaired lung just as the constricted pericardial layers impair and impede the heart in constrictive pericarditis But the pleural membrane itself retains to an astonishing degree a normal anatomy even when massive deposits of fibrin, later organized into fibrous tissue, become incorporated with it through the medium of small blood vessels and this quality enables the surgeons to remove these super-imposed layers of fibrous tissue in the operation of pulmonary decortication in the treatment of empyema, organizing haemothorax and of some lungs that fail to re-expand after artificial pneumothorax treatment

THE LYMPHATICS OF THE THORAX

Appearances at operations on the lungs, oesophagus and mediastinum have amply verified the accurate description of the thoracic lymphatics given by anatomists Of special importance is the enlargement of those glands that lie close to lobar bronchi, for this frequently causes such obstruction that atelectasis develops In tuberculous disease such a collapse most frequently affects the right upper lobe and the middle lobe (" the middle lobe syndrome ") This type of lymphadenopathy forms a striking feature of the primary tuberculous complex

Certain particular groups of glands are of special importance to the thoracic surgeon Of the extrathoracic ones particular attention is paid to the aggregation of nodes above the clavicle which may be infiltrated in patients with carcinoma of the stomach, oesophagus and lungs , exceptionally this group may be attacked by tuberculosis when there is disease of the apex of the lung , occasionally the axillary glands are invaded by malignant tumour masses originating in bronchial carcinoma but this is quite exceptional

The inferior tracheo-bronchial glands are often massively involved by extension from bronchial carcinoma and the normally sharp carina may be converted into a smoother bulge

significant of this invasion when viewed through the bronchoscope The glands of the superior mediastinum form a larger group on the right than on the left side and have important connections with those that form a chain above the level of the azygos vein with the glands lying alongside the upper oesophagus and with the nodes of the left lung hilum Gross enlargements of these glands on both sides may be a contra indication to radical excision for carcinoma of the lung or oesophagus Their enlargement secondary to bronchial carcinoma may be detected by a careful study of the pre-operative barium meal studies of the oesophagus Metastases from one lung to the other in carcinoma of the lung is unusual but lymphatic spread to glands of the other hemithorax is not so rare

The glands of the superior mediastinum are perhaps the earliest to be involved by lymphadenoma Usually there is a small lymphatic gland overlying the ligamentum



Fig 1 9



Fig 1 10

Fig 1 9 —Carcinoma of the oesophagus with gross involvement of the mediastinal glands on both sides. Oesophagoscopy confirmed the diagnosis of carcinoma made on the barium swallow picture and the biopsy was "squamous carcinoma

Fig 1 10 —Left pneumonectomy had been performed 8 months before this radiograph was taken. At the operation the left superior mediastinal glands were clinically infiltrated by growth the right group of gland are now extensively invaded and there commencing atelecta is of the right upper lobe

arteriosum or the patent ductus arteriosus which is of some surgical significance as when enlarged it may impede the dissection that precedes ligation

In the lower part of the thorax important collections of lymphatic glands envelop the lobar supply both arterial and bronchial to the main lobes Such glands when enlarged may not only produce extrabronchial pressure sufficient to cause atelectasis but present surgical difficulties when dissection lobectomy or segmental resection is being undertaken Especially important is the enlargement of lymphatic glands around the middle lobe bronchus which is vulnerable to such pressure and often collapses as the result (the middle lobe syndrome) A curious fact is that gross inflammatory enlargement of intrathoracic glands rarely proceeds to suppuration though in tuberculous affections caseous material may rupture into a bronchus occasionally this is noted bronchoscopically in epituberculosis

of the right upper lobe bronchus In lower lobectomy a lymphatic gland just below the lower border of the inferior pulmonary vein lying in the ligamentum latum pulmonis is encountered when that vessel is being isolated preparatory to its ligation

The intercostal spaces contain lymph nodes at the posterior as well as the anterior part of the compartments As is well known the intercostal nodes may be invaded by carcinoma of the breast, but they are important also as seats of caseating tuberculosis If such glands break down the resultant abscess may point above the sternum and be regarded as evidence of tuberculous disease of that bone Caseation and cold abscess formation may also develop in the posterior intercostal glands and track along the subcostal groove of the overlying rib Most so-called tuberculous abscesses of ribs are indeed due to this type of disease and the resection of a portion of the rib at the site of the cold abscess is often inadequate, as pointed out by the late J E H Roberts some years ago The posterior intercostal glands are frequently seen to be involved in caseating tuberculosis in chronic upper lobe disease during the course of Semb's extrafascial apicolysis or during an extrapleural upper lobectomy

CONGENITAL ABNORMALITIES OF THE LUNG

Many of these anomalies may imitate an acquired pathological process or be the occasion of complicating disease, and their recognition radiologically or during the course of a thoracic operation is of greater importance than their relative rarity would indicate In the literature of thoracic surgery it has become increasingly apparent that many so-called congenital lesions are in fact acquired and this applies especially to " congenital " cystic disease of the lur On clinical and gross pathological examination many " cystic " lobes suggest an embry logical etiology, but a careful survey of the evidence frequently indicates that the specim under consideration is in fact one of acquired saccular bronchiectasis Obvious congenit abnormalities do, however, present in all parts of the thorax, ranging from tumour supposed to be of teratomatous origin but frequently due to f primitive tracheo-oesophageal tube, through obvious anomal partial or complete agenesis which may include one or, qu The complete absence of both lungs has been noted in an 8 mont larynx was developed but the trachea was still in full continuation um have amply there were no main stem bronchi The failure of bronchial develo ts Of special occurred at the fourth week of intra-uterine life (Schmidt—quoted by

is the so-called lower accessory lobe Because of this it may be helpful to discuss briefly the position of congenital cystic disease of the lung

Congenital cystic disease It is always tempting to diagnose congenital cystic disease from radiological appearances in which circular air spaces are visible or in which lipiodol bronchography reveals spherical oil filled cavities but such an appearance usually represents acquired bronchiectasis If the cysts are isolated from the bronchial tree they are probably congenital in origin an assumption supported by the smoothness of a lining which may show a well-differentiated mucous membrane consisting of ciliated epithelium of bronchial pattern (Fig 1 14*b*) As Gruenfield and Gray (1941) suggest a factual description is preferable to a classification based on assumed congenital etiology if on radiological or pathological examination the cysts are small and multiple a descriptive term such as honeycomb lung should be used the term air cysts or pneumatoceles being applied to the larger variety

It is indeed difficult to differentiate acquired from congenital bronchiectasis even on the fullest histological examination The presence of inflammatory processes will not serve much in the differentiation, for congenital cystic bronchiectasis is often complicated by the addition of pyogenic inflammation

The academic differentiation of congenital from acquired cystic disease is fortunately not of great clinical value for the treatment adopted (resection or conservatism) depends on the symptoms present and the actual state of the patient irrespective of etiological factors Cystic bronchiectasis may be a congenital malformation of the bronchioles or alveoli through inherent lack of elastic tissue or the result of bronchial obstruction (congenital or acquired) or to inflammatory processes The previously held opinion that honeycomb appearances due to congenital disease were commoner in the upper lobes than in the lower paid too little attention to the possible effects of a healed fibrotic tuberculous process which is commoner in the upper lobe and to the prolonged effect of atelectasis produced by the compressing action of tuberculous glands

Large solitary cysts of the lung

Without labouring over complicated classifications these cysts may be fluid or air containing and it is difficult or impossible to separate the latter from areas of emphysema (pneumatocele) a lining of ciliated epithelium is the rule in fluid-containing cysts (see Fig 1 13) They may be classified as upper or lower accessory cysts Both types may represent aberrant budding off of lung tissue which may present in an accessory lobe as in Fig 1 13 this cystic area had a lining of bronchial type epithelium. The rare type of fluid containing cyst resembles the bronchiogenic cyst found in the mediastinum (see p 487) These may rupture into a bronchus with the development of a fluid level.

Lower accessory lung (dissociated sequestrated or reduplicated lobe)

Because the abnormal lung tissue may be a large cyst or a mass of ill-developed tissue (Fig 1 14) firmly united to the associated normal lower lobe there has been some confusion in reporting these cases in the literature If both types of condition are considered the condition is of reasonable frequency in thoracic surgery and I have operated on eleven such patients nine had cysts in the left lower chest and two in the right The academic arguments range between two theories (*a*) that the tissue mass represents an area of reduplicated or accessory lung tissue derived from an extra lung bud (Baar and d Abreu 1949) or (*b*) that it represents a portion of lung sequestrated and detached from a normally developed lobe

of the azygos vein which curves so laterally on its way to join the superior vena cava that it splits off a medial portion of the upper lobe, carrying into the fissure so made a pleural fold which encircles the extrapleurally placed azygos vein This fold is clearly seen on the postero-anterior radiograph (Fig 1 7) The vascular and bronchial supply of the " lobe " is by normal arrangement for the apical segment The azygos lobe may be the site of disease such as tuberculosis and I have once resected it when it was the seat of a chronic lung abscess which radiologically produced the appearance of a mediastinal tumour, not unlike a laterally placed intrathoracic goitre

Accessory lobes or lungs

These are rare but interesting , they may be found in the neck, thorax or abdomen. A separate classification into two groups is at once possible those with normal bronchial connections and those without any communication with the bronchial tree



Fig. 1 12



Fig. 1 13

Fig 1 12 --A tracheal lobe
The probe is in the tracheal orifice which leads to a lobe comprising two separate segments with complete fissure
(Dr H Barr Children's Hospital, Birmingham)

Fig 1 13 --Upper cystic accessory lobe (*Brit J Surg*)
At autopsy this upper cystic lobe had a separate bronchial and blood supply and was lined by well-developed bronchial epithelium

In the first group may be quoted the instance of the tracheal lobe, and in the second the so-called accessory lower or dissociated lung mass and the discovery of pulmonary masses in the abdomen usually below the left diaphragm , of greatest clinical importance

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During the early phase of embryonic life the development of the lung may be irre and accessory masses of lung tissue may arise These ectopic formations sometimes desc as " dissociated " lung (Pryce, Sellors and Blair, 1947) usually have a bizarre arterial b supply from the aorta , in the commonest variety there is cystic formation of the lower and the supplying systemic artery, often a large one, usually arises from the aorta just passes up through the diaphragm to ramify in the dissociated lung mass (Fig 1 15) Du the operation of lower lobectomy on a cystic lung the possible presence of such an ar

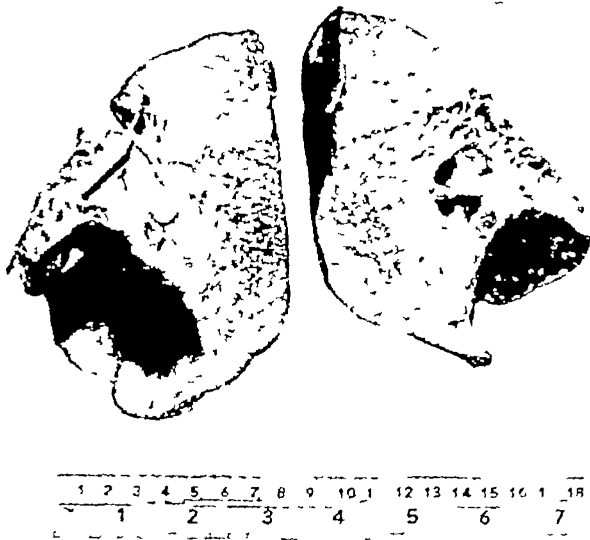


Fig 1 14



Fig 1 15

Fig 1 14 —Accessory lower lobe

The probe is in the systemic artery which arose from the abdominal aorta to supply the dissociated mass of lung tissue Lobectomy specimen

Fig 1 15 —The pulmonary artery supplying the lower lobe and the systemic vessel supplying the "accessory " lobe have been injected with lipiodol

There is no communication between the vascular or bronchial supply of these two sharply demarcated areas of tissue

must always be in mind otherwise the division of a supposed stout adhesion may caus possibly fatal haemorrhage (Douglass 1948)

In one of my patients there was a large congenital diverticulum of the oesophag present (see Fig 19 17) and in another a hernia of the stomach through the oesophageal hiat

These aberrant lung masses may represent types of reduplication of the foregut Sir the lung buds and the oesophagus have a common origin such out-budding may be prese as in the small intestine where reduplication and enterogenous cyst formation is accept as being the outcome of such a type of maldevelopment

The histological structure of the vessel that enters the dissociated cystic mass is th of a pulmonary artery The condition is important because infections develop in t apposed neighbouring lobe and because of the peculiarity of its blood supply In my elev patients the diagnosis had been empyema, lung abscess or bronchiectasis because all t

cysts were infected When the dissociated lung mass is incorporated in a lower lobe the condition usually will be diagnosed and treated as bronchiectasis because infection has involved the normally developed lobe the exact diagnosis will be made at operation when an accessory vessel is seen during the course of a lobectomy Since the abnormal vessel is often in the region of dense adhesions near the pulmonary ligament the possibility of its presence should be remembered before adhesions are divided during resections of the lower lobe Occasionally haemorrhage may occur if a large cyst regarded as an empyema is treated by rib resection and drainage

CONGENITAL COMMUNICATIONS BETWEEN PULMONARY ARTERIES AND VEINS

Abnormal malformations of blood vessels in the lung are difficult to classify but are probably of congenital origin and will be described briefly here rather than under a discussion on hamartomatous formation or as a cause of cyanosis The communications may be described as arterio venous fistula cavernous haemangioma or pulmonary telangiectasis

The pathological basis of an arterio venous shunt in the lung is of less practical importance than the resultant physiological changes that develop Once the condition is suspected the establishment of the diagnosis is not difficult A shunt between the pulmonary artery and the pulmonary vein sufficient to cause dyspnoea cyanosis and a compensatory polycythaemia is usually due to an angioma of the lung the blood by passing the normal capillary bed and not being oxygenated This may be associated with telangiectasis else where when the condition is often familial especially in the lip mouth and tongue (Osler s disease) The condition may involve both lungs (50 per cent of the reported cases) (Janes 1944) and quite rarely undergoes malignant transformation even producing metastases Angioma of the lung may be of sufficiently small size to be quite unassociated with any circulatory disturbances Frequently a dilated tortuous pulmonary artery enters a large sac from which the blood passes on to the vein the intima of the arterial vessels is normal but there is very little muscle detectable in their walls The pulmonary vein histology is normal the lesion clearly being a varicosity of the arteries exclusively as is the case in cerebral angiomata The recognition of the condition is specially important because surgical cure is often simple The first lung resection in this condition was carried out by Shenstone in 1940

Symptoms and signs There may be none if the shunt is small Autopsy records indicate that angiomata may have been present in life without occasioning any symptoms and it is possible that in some of these patients the malformations had involved the bronchial vessel systems so that no communication existed between the pulmonary artery and vein and therefore no appreciable shunt existed Cyanosis dyspnoea and haemoptysis (some times fatal) may be combined the cyanosis may have dated from early life but this is not invariable (One of our patients a man of 27 suddenly developed symptoms of dyspnoea and cyanosis seven years before admission for surgical treatment) Telangiectasis may appear quite suddenly on the skin and mucous membranes and the same process is at least possible in the lungs but once developed it is progressive Cough is present in some patients and its association with clubbed fingers and toes (an invariable accompaniment of lung arterio-venous fistula associated with symptoms) may lead to the patient s reference to a chest clinic as suffering from bronchiectasis The anoxaemia present may cause cerebral symptoms and nose bleeding has been noted

Polycythaemia is marked the heart does not enlarge as in arterio-venous aneury involving the greater systemic circulation and the cardiac output is not increased since blood pressure is not raised as it is in the systemic type of fistula In more than half patients a systolic murmur is audible over the affected lung area and if the lesion is pla superficially a thrill may be felt , the murmur becomes louder on inspiration

Radiological studies of the chest reveal an area or areas of increased density and study of these is helped by tomography and by angiocardiography The shadows enla on inspiration The opacities are usually irregular and the vessels leading to them dilated, enlarged and tortuous The discovery of lung opacities in a patient with club fingers and toes, cyanosis and polycythaemia should at once suggest the possibility of arterio-venous fistula, in the absence of evidence of congenital cardiac disease. Mi (1948) has described an unusual complication of bacterial infection Cardiac catheterizat and physiological studies not only confirm the diagnosis but enable an estimate of the s of the shunt to be made The history, physical signs and laboratory studies are v exemplified by the following case history

F E , a man of 25, was referred to Dr Brian Taylor for persistent cough, cyanosis and brea lessness which had developed progressively over a period of six years , pneumonia had b diagnosed at the age of 11 He was obviously cyanosed and the fingers and toes were clubb a few rales were present at both bases, but the main physical sign was a systolic bruit over base of the left lung , the diagnosis was that of arterio-venous fistula and a lipiodol bronchogr excluded any associated bronchiectasis There was no telangiectasis of the lips or mouth or any cutaneous surface The blood picture revealed a polycythaemia (6,500,000) Tomogra and angiocardiographic studies demonstrated dilated vascular channels in the left lower lo The electrocardiograph showed a left ventricular preponderance

Cardiac catheterization and arterial blood estimations were carried out (Dr Paul Davison The results were as follows

	Pressure (mm Hg)	O_2 Content, vol per cent	Percent O_2 saturati
Main pulmonary artery	20/7	7 86	47 5
Mid-right auricle	—	8 14	49·2
Right femoral artery breathing air	—	11 94	72 2
Right femoral artery inhaling pure oxygen	—	13 50	81·6
Oxygen capacity of blood	—	16·54	100 0
Normal pulmonary veins (calculated 95% saturated)	—	15 72	95 0

Metabolic rate = 335 c c oxygen per minute

The pulmonary artery pressure was normal the low oxygen saturation of the arterial blo (72 per cent) not converted by oxygen inhalation (82 per cent) confirmed the presence of a lar intrapulmonary shunt. Assuming that the mixed venous blood passing through normal lu becomes 95 per cent saturated with oxygen and that the blood going through the arterio-veno aneurysm receives no oxygen the size of the shunt was calculated as follows

(1) Arterio-venous oxygen difference

Femoral artery — mixed venous blood $= 11\ 94 - 7\ 86 = 4\ 08$

Normal pulmonary venous blood — mixed venous blood $= 15{\cdot}72 - 7\ 86 = 7\ 86$

(2) Therefore on the Fick Principle

(*a*) Total pulmonary blood flow $= \frac{335}{40\ 8} = 8\ 21$ litres/minute.

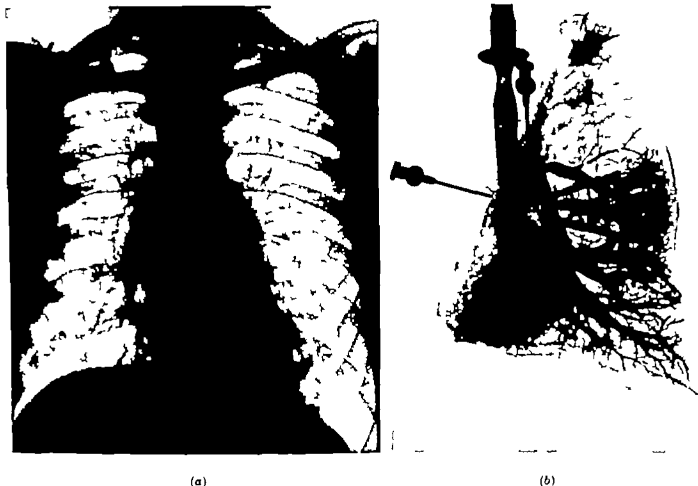
(*b*) Blood flow through normal lung capillary bed $= \frac{335}{78\ 6} = 4\ 26$ litres/minute

(3) Therefore the size of the pulmonary shunt $= 8\ 21 - 4\ 26 = 3\ 95$ litres/minute

or $\frac{3\ 95}{8\ 21} \times 100 = 48$ per cent

The shunt was taking about half the blood flow through the lesser circulation

A left lower lobectomy was therefore done The cyanosis disappeared immediately the pulmonary artery to the lobe had been ligated the patient recovered rapidly and all symptoms disappeared Three weeks after operation the arterial oxygen saturation was normal



(a) (b)

Fig 1 16

(a) Arterio venous fistula of lung
Radiograph showing abnormal shadow in left lower lobe i a man with cyanosis

(b) Radiograph of left lower lobe excised for arterio venous fistula
The pulmonary artery supplying the lobe has been filled w th lipiodol, which is entering into a mass of dilated essels which drain off by large cha nel int the inferior pulmonary v in

As expected cardiac catheterization in the case described showed the cardiac output to be normal and no rise in the pressure in the chambers because of the satisfactory way in which the pulmonary circulation accommodates a large extra flow of blood great enough in the case above to produce approximately a 50 per cent shunt

Differential diagnosis Cyanosis and dyspnoea associated with polycythaemia is more often due to congenital heart disease than to arterio-venous fistula of the lung In congenital heart disease the findings of cardiac signs by auscultation and radiography will at once establish the source of the polycythaemia confusion with polycythaemia vera is avoided if splenic enlargement is detected and is easily excluded if a murmur is heard in the chest and if tomography and angiocardiography is undertaken in the presence of doubtful lung opacities

Surgical treatment The only hope of cure is by excision of the angioma and this is indicated if symptoms are at all severe this may be done by segmental resection Janes (1944) first recorded multiple resections two angiomata being removed from the right lung

followed at a later stage by resection of another from the left side. Lobectomy or pneumonectomy dependent on the location and extent of the blood vessel abnormalities may be necessary. If the condition is bilateral the extent of the resection must be as conservative as possible: for this reason angiocardiography should be performed before operation as this not only outlines the extent of the condition but may show up angiomatous areas unrevealed by straight radiography. Before operation is undertaken the surgeon must be quite certain that no area of shunt is undetected

Because of the risk of phlebo-thrombosis in any patient with polycythaemia an adequate fluid balance must be maintained during and after operation An intravenous saline drip is set up during the operation. blood not being given unless severe bleeding takes place

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of the order of 160 litres per minute. In more athletic persons values over 200 litres per minute have been recorded. These remarkable amounts of air are shifted by the subject while at rest and are in no way related to any physiological demand such as exercise. Ventilatory volumes of this order are never reached during the most violent exertion, even when a normal person exercises to utter exhaustion and agonizing shortness of breath. It has been shown that, if the volume ventilated during exertion is more than a third of the maximum breathing capacity, then ventilatory discomfort will be experienced. This discomfort, or dyspnoea, increases as the ventilatory volumes increase and when half the maximum breathing capacity is reached, then even a normal person will be very uncomfortable and short of breath. Thus, if an attempt is to be made to quantitate the degree of dyspnoea of a person under given conditions, the maximum breathing capacity must first be measured and then the actual volumes ventilated related to that figure. It cannot be over-emphasized that although the maximum breathing capacity is a most useful empirical measure of the ventilatory function or the bellows action of the lungs, it does not represent the maximum amount of air that can be ventilated in response to normal physiological stimuli such as exercise. The true ventilatory capacity, defined as those volumes which can be ventilated during exercise without undue distress, is slightly less than half the maximum breathing capacity.

*What are the factors that reduce the ventilatory capacity? Any form of tracheo-*bronchial or bronchiolar obstruction will interfere with the free passage of air in and out of the lungs. Bronchospasm will cause such obstruction and greatly reduce the ventilatory capacity. In both the bronchitic and asthmatic subject, congestion and oedema of the bronchial mucosa and secretion contribute to this obstruction. If bronchial obstruction continues over a long period then pulmonary emphysema will develop, the lung substance itself becoming distended and inelastic. This loss of lung elasticity, which is also associated with an expanded and relatively fixed thoracic cage, will also cause considerable reduction of the ventilatory capacity, interfering particularly with the normal expiration which depends more upon the natural rebound of the lung and chest than upon active muscular effort. In most cases of emphysema there is some element of bronchospasm and these two factors combine to lower ventilatory efficiency. Attempts are made to assess the obstructive factor by determining the increase in the maximum breathing capacity after adrenaline injection or inhalation, but this increase is never of the same order as that after a natural remission of bronchospasm.

The ventilatory capacity (as measured by the maximum breathing capacity) is considerably affected even in relatively mild emphysema and, although there is much more work to be done on the normal values in persons of different ages and body size, there is usually no difficulty in recognizing that there is a significant reduction of the ventilatory capacity. Care must be taken in relating these figures to published findings in normal persons. If possible, the maximum breathing capacity of normal subjects of different ages, sex and sizes should be determined with the particular apparatus used.

The main disability in pulmonary emphysema is the impairment of the ventilatory capacity. It is the primary cause of the shortness of breath which is the conspicuous symptom of the disease.

In patients with pulmonary fibrosis (i.e. pneumokoniosis) but without emphysema there is rarely any marked impairment of the ventilatory capacity. This is because there is little, if any, bronchospasm and the lungs are not overstretched and are still able, by virtue of their elasticity, to force the air rapidly out of the chest when inspiration ceases. However, if bronchitis, bronchospasm, emphysema, or marked lung deformity from massive

scarring occur then the ventilatory capacity will fall considerably A number of patients with pulmonary fibrosis show abnormally increased ventilation on exertion and this will contribute to their shortness of breath

Ventilatory considerations before lung resection

Providing resection of lung does not cause intolerable right heart embarrassment or fatal anoxaemia both rare events the limiting factor as regards activity after operation is the ventilatory capacity If this is greatly impaired then the patient will be unduly short of breath on exertion High ventilatory volumes on moderate exertion will also contribute to this dyspnoea

Before operation the maximum breathing capacity and the volumes ventilated while walking at moderate speed can be easily determined It is now established that the volume of air ventilated during a fixed degree of activity is rarely significantly altered by any resection or collapse procedures Thus if the effect of the operation on the ventilatory capacity can be foretold and it is known that it will remain more than two and a half times the walking ventilation then the patient will be able to walk at reasonable speed without undue discomfort Unfortunately the effect of various procedures on ventilatory capacity can only be predicted by intelligent guessing guided by previous experience Waring (1949) screens the patient and watches rib and diaphragmatic movement and the lighting up and emptying of the lung fields on each side during quiet and forced respiration He has developed a remarkable ability to foretell the post-operative ventilatory capacity using a somewhat empirical system of marking the rib and diaphragm movement on each side The fact that a patient with one normal remaining lung which is not distended or deformed maintains by more rapid respirations a ventilatory capacity which is little below that of a normal subject with two healthy lungs renders such quantitation exceedingly dubious Nevertheless the method is of value and gives those who employ it a considerable insight into the problem of ventilatory sufficiency Waring also follows the maximum breathing capacity during various stages of a doubtful pneumothorax or thoracoplasty and is able to assess with reasonable accuracy the risk of making the patient a ventilatory cripple at each stage

This problem of assessing the loss of ventilatory capacity that may follow various procedures remains a great challenge to workers in this field It is unlikely that broncho spirometry will help except in those cases where the lung to be removed is shown to be functionless Even in such cases if the remaining lung is damaged or deformed by the operation then a further loss of ventilatory capacity will result

All authorities are now agreed that a maximum breathing capacity of 35 litres per minute or less renders any operative interference out of the question

There is the occasional problem of a patient with an apparently operable carcinoma of the lung and considerable emphysema If the patient had little respiratory disability before this illness then it is unlikely that he has true emphysema Clinical and radiological assessment of this disease can be very misleading but the demonstration of a relatively unimpaired maximum breathing capacity will often reassure the surgeon If however the patient suffered from shortness of breath for some time before the development of the growth and the maximum breathing capacity is low he may well be a ventilatory cripple after resection and the decision to operate must rest with the patient and his medical adviser Usually resection is carried out and although the ventilatory capacity may be so reduced that the patient is unable to walk in comfort there have been gratifying and surprising results At this age life is sweet even in an armchair

Before passing on to the consideration of lung volumes, mention should be made of the factors causing excessive ventilation on exercise, these are ill-understood If there are considerable areas of lung which are still ventilated, but have impaired circulation, then this ventilation is wasted, so far as gas exchange is concerned, and the added burden of ventilating this relatively functionless lung will cause a proportionate increase of the total ventilation There is good evidence that this so-called "dead space effect" can be considerable in lung disease, especially in emphysema (Donald, 1952)

If, owing to the poor correlation of ventilation and perfusion in the lungs, or reduction or abnormality of the effective blood-gas interface where oxygen transfer can take place, there is considerable arterial anoxaemia on exertion, then there will be a marked increase of ventilation Anoxaemia, although only a mild respiratory stimulus at rest, causes a great increase of pulmonary ventilation if associated with exercise Thus marked cyanosis, due to arterial blood desaturation on exercise, is important, in this respect, as it causes large ventilatory volumes which may give rise to considerable discomfort, even if the ventilatory capacity is not greatly reduced

Hyperventilation due to anoxaemia is particularly important in those patients who maintain a good ventilatory capacity despite abrupt arterial desaturation on exercise (alveolar wall infiltration causing diffusion disturbances and congenital heart disease provide examples) It is not so important in those diseases where the ventilatory capacity is greatly impaired (emphysema)

This powerful anoxaemic hyperventilation on exercise will wash carbon dioxide out of the body and the buffers (alkali reserve) will fall accordingly This, again, will render the respiratory centre more sensitive to carbon dioxide and hydrogen ions and tend to perpetuate high respiratory volumes, even at rest In the later stages of emphysema there is temporary retention of carbon dioxide due to ventilatory insufficiency, each time the patient exercises In such cases the body buffers will increase and when the body and lung carbon dioxide become permanently raised the ventilatory volumes fall owing to relative insensitivity of the respiratory centre to carbon dioxide stimulation It is, of course, not a true insensitivity but an increased chemical protection of the respiratory centre

Finally, many authorities postulate that increased ventilation may be reflex and due to the pathological processes in the lungs increasing the sensitivity of the Hering Breuer reflex There is, as yet, no convincing proof of this

This brief account mainly emphasizes our ignorance of this important aspect of lung function, but it is fortunate that the ventilatory demands can be directly measured in any particular case during a fixed degree of activity Gray's valuable monograph on the *physiological regulation of pulmonary ventilation* is to be recommended (1950)

Lung volumes

The lung volumes are the boundaries within which ventilation takes place It is now generally agreed that too much emphasis has been placed on this aspect of lung function Although these measurements are useful in a full and detailed study of any patient, they are of less value when considered alone, and it is most unwise to make general conclusions concerning respiratory function from their study alone

Fig 2 1 shows the lung volumes using Christie's terminology (1932), which has been in general use for some time in Britain. Fig 2 2 shows the new terminology, agreed upon by a large number of workers in the field (Pappenheimer, 1950) In the author's opinion this terminology is a considerable improvement, as the terms are more self-explanatory and the use of the word "air" to describe a volume is avoided.

The maximum volume the lungs can attain is termed the *total capacity* the minimal volume the *residual volume* The difference between these two volumes which represents the maximum volume of air that can be expired after a maximum inspiration, is by

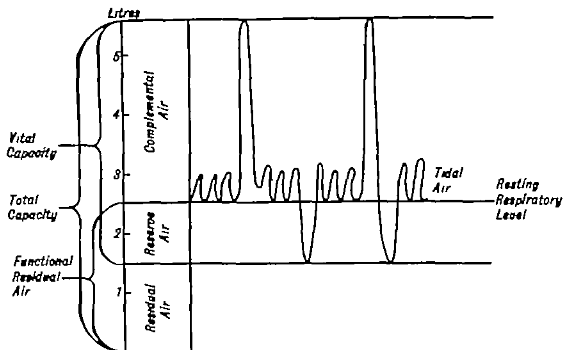


FIG 2 1—The lung and its subdivisions. (R. V Christie 1932)

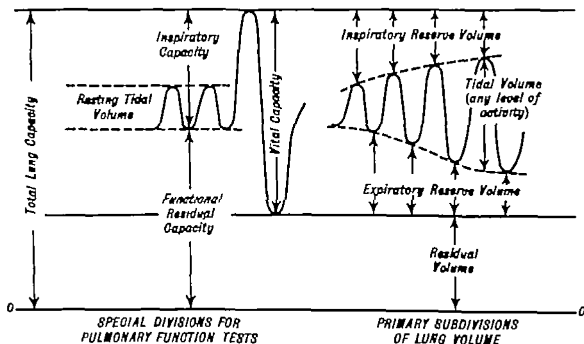


FIG 2 *—Subdivisions of the lung volume (J R Pappenheimer 1950)

Hutchinson's definition the *vital capacity* The volume of air in the lungs at the end of a quiet expiration is the *functional residual capacity* As most spirometric studies are from respiratory charts this base line of quiet respiration is known loosely as the resting respiratory level a convenient but unscientific term

The vital capacity is easily measured in any closed circuit and usually a tracing is taken The inspiratory capacity and the expiratory reserve volume are the two components of the vital capacity which are measured from the "resting respiratory level" As these volumes are measured outside the body, they must be converted to body temperature (saturated with water vapour) It is now common experience that the vital capacity, and its subdivisions, *although frequently* decreased in respiratory disease, are, in any individual case, a most unreliable index of general *respiratory or ventilatory function* Although a study of the lung volumes gives an accurate assessment of the size and range of the lung bellows, it is a static volume measurement and gives no indication of the efficiency and speed of ventilatory movements within this range

It was hoped that the determination of the residual volume and total capacity would add greatly to the value of lung volume measurements. The volume of gas in the lungs can be determined by a number of indirect methods The one most often used in this country depends upon measuring the degree of dilution of a known volume of an inert physiologically inactive gas, such as helium, in the lungs The other common method, which is extensively used in America, depends upon the measurement of the change of the percentage of alveolar nitrogen after seven minutes' oxygen breathing The expired gas is collected and the determination of the absolute amount of nitrogen washed out by the oxygen allows the volume of gas in the lungs to be calculated

Both these methods give satisfactory results The determination is carried out during quiet respiration, the patient being connected to the circuit at the end of a normal expiration Thus the functional residual capacity is obtained, and the residual volume determined by subtracting the expiratory reserve volume, which is measured before, or after, the experiment

The residual volume can be expressed in absolute terms or as a percentage of the total capacity This volume is normally 20–25 per cent of the total capacity, but up to a third (33 per cent) *of total capacity is now considered within normal limits* However, it must be emphasized that it is not unusual to find middle-aged persons with no lung disease or dyspnoea, with residual volumes which are 40–50 per cent of a normal total capacity Although in general the residual volume is considerably increased in pulmonary emphysema, this increase is not directly proportional to the degree of disability Very moderate cases of emphysema, who are *but little handicapped, have residual volumes over 50 per cent* of the total capacity, and others who are respiratory cripples with considerable cyanosis have but little increase of the residual volume Furthermore, with few exceptions, the total capacity in emphysema is within the normal range Thus as the total capacity is the sum of the residual volume and the vital capacity, it is to be expected that assessing the respiratory disability by the increase of residual volume will be as disappointing as assessing it *by the reduction of the vital capacity*

In most cases of lung fibrosis or generalized pulmonary infiltration (Boeck's sarcoid, neoplastic infiltration, granulomata) the total lung capacity is reduced, and its various subdivisions are proportionately decreased In some patients, however, the residual volume will be normal, in absolute terms, and thus *more than 33 per cent of the total* capacity It is at present *impossible to diagnose superadded emphysema in such cases by* lung volume studies alone

When there is unilateral fibrosis or collapse, or different types of damage on the two sides the accurate interpretation of lung volume data by external spirometry is impossible The study of lung volume on each side by bronchospirometry, a tedious procedure, is an advance, but even this method is full of difficulties. Lung volume changes may be due to

actual emphysema or fibrosis or to mechanical events in the chest such as mediastinal shift collapse pleural changes or diaphragmatic paralysis

Finally lung volume data are useful when considering every aspect of a difficult respiratory problem, but the time and trouble taken to determine the residual volume is only justifiable in large units which are well equipped with both apparatus and personnel

Lung circulation

The pulmonary circulation is a low pressure system. The short distensible and capacious pulmonary arteries arterioles and pre-capillaries and the enormous network of large pulmonary capillaries surrounded by air allow the whole cardiac output to flow through the pulmonary vascular bed with a pressure head of only one-sixth of that in the systemic circulation Even marked exertion with a fourfold increase of cardiac output will cause little or no rise in the pulmonary artery pressure (Riley 1948 Dexter 1951) The only factor known to cause a significant rise of pulmonary artery pressure in normal subjects is the breathing of low tensions of oxygen (Motley 1947) The determination of pulmonary artery pressures involves cardiac catheterization (see Chapter 15) and on the whole this is only necessary when the natural history of pulmonary hypertension in various lung diseases is being studied

In emphysema the pulmonary artery pressure at rest is only slightly raised even in patients with long histories and severe lung damage This is not altogether surprising as the clinician has long known that the majority of emphysematous patients with gross ventilatory insufficiency have small vertical hearts When these subjects exercise there may be a considerable rise of the pressure in the pulmonary artery It is possible that the right ventricle of these patients is protected by their inability to carry out any sustained exertion owing to extreme ventilatory discomfort

Those patients with pulmonary emphysema and a large heart due to right ventricular hypertrophy are usually first seen when in acute congestive failure precipitated by a severe anoxic episode such as bronchopneumonia This would suggest that their ventilatory disability has not been marked and that they have been able to carry out considerable exertion with associated pulmonary hypertension over long periods In time this will inevitably cause right ventricular hypertrophy Any added burden such as severe anoxia due to pneumonia or severe bronchitis with respiratory obstruction may precipitate right heart failure

The natural history of pulmonary hypertension and right-sided heart failure in lung fibrosis severe bronchiectasis or fibrocaseous tuberculosis is still not yet adequately studied

Cournand (1949) has shown that if a normal lung remains after pneumonectomy and it is not unduly damaged or distended by scoliosis or by mediastinal shift then this single lung can accept the cardiac output in all degrees of exertion encountered in a normal existence without any rise of pulmonary artery pressure Although some rise of pressure has been shown on extreme exertion some of these patients have lived normally and even indulged in tennis and swimming for up to ten years with no evidence of right ventricular hypertrophy

Occasionally a lung resection will cause unexpected and irreversible right sided heart failure With the rapid development of chest surgery there is an urgent need for greater knowledge of pulmonary haemodynamics in various diseases and after resection In long standing or bilateral lung disease where resection is visualized great care should be taken not only to consider the ventilatory capacity but also the state of the pulmonary circulation

and the right heart A loud pulmonary second sound should be looked for and the right ventricle examined clinically, by screening, and electrocardiography (Myers, 1948)

If there is any doubt concerning this aspect then cardiac catheterization, if available, should be carried out At present there is not enough data to allow a definite opinion concerning the safety of resection to be given in each case, but these important ancillary investigations should be used more frequently and, with increasing experience, they will become more and more valuable

Hansen and Carlens (1950) are developing a method whereby the pulmonary artery of the lung to be resected is occluded by a balloon on a cardiac catheter, and any undue rise of the pressure in the main stem of the pulmonary artery during moderate exercise on an ergometer can then be demonstrated Other workers carry out continuous observation of the pulmonary artery pressure during any " dubious operation " by means of an intracardiac catheter (Mendelsohn, 1950) The pulmonary artery of the lung to be resected is then gently clamped and the pressure in the main stem, which should return to normal in a few minutes, is noted. These methods are not yet fully developed, but they show that this problem can be, and no doubt will be, solved The first and most important step is to be aware of the problem

Finally, it is most important to avoid anoxia post-operatively, particularly in those patients who may be in danger of right heart failure Traumatic and infective oedema, collapse, pleural effusion and haemorrhage, and bronchial irritation and blockage all combine to prevent adequate ventilation and oxygenation of blood passing through the lungs. Further, the low oxygen tensions in many parts of the lung will almost certainly cause pulmonary vasoconstriction and increased work for the right heart which is already handicapped by arterial anoxaemia These patients should be maintained in an oxygen tent until the clinician is satisfied that alveolar ventilation is restored, as evidenced by the disappearance of cyanosis If there is any doubt, arterial puncture should be performed and the arterial blood oxygenation precisely determined These post-operative cases are in no danger of carbon dioxide retention while in high tension of oxygen This phenomenon is only encountered in very long-standing cases of emphysema, who have retained large quantities of carbon dioxide which are buffered by increasing the alkali reserve As a result of this the respiratory centre is relatively insensitive to carbon dioxide and the anoxic stimulus to respiration plays a large part in the maintenance of ventilation If such patients are kept in high oxygen tensions, particularly when the anoxaemia and carbon dioxide retention have been recently increased by a severe respiratory infection, then their ventilation will fall dramatically and although they are not cyanosed, they will acquire body carbon dioxide tensions which render them unconscious However, such patients will not reach the thoracic surgeon and carbon dioxide intoxication is a problem that concerns the physician

Blood oxygenation

Cyanosis is caused by an undue amount of reduced haemoglobin in the peripheral circulation It is most noticeable in the regions where there is a generous capillary bed (nose, cheeks, ears hands, feet) or in the mucous membranes There are two main causes of cyanosis If the blood passing up the aorta is inadequately oxygenated then the cyanosis resulting from this is termed " central cyanosis " This state of affairs is found in congenital heart disease. where unchanged mixed venous blood is shunted across into the left heart without passing through the lungs, and in various lung diseases where, although the blood flows through the lungs, it is still inadequately oxygenated.

The second main cause of cyanosis is a low cardiac output due to impaired cardiac efficiency There is a considerable peripheral and cutaneous vasoconstriction which no doubt conserves heat and maintains an adequate blood pressure despite the decreased inflow into the arterial system The maintenance of an adequate arterial blood pressure is essential for the blood supply of the brain and other vital organs and if this compensatory vasoconstriction fails (peripheral failure) then the patient is in grave danger The thoracic surgeon who is now operating more and more on patients with low systemic blood flow (mitral stenosis and many congenital heart diseases) must be constantly aware of this hazard and every detail from room temperature to the gentle handling and retraction of tissues must be considered with care to avoid the not infrequent situation of a successful operation followed by irreversible peripheral failure

To return to the consideration of patients with peripheral cyanosis If an arterial puncture is carried out then it can be shown that the blood from the left heart is well oxygenated A number of patients in low output heart failure may show slight desaturation of the arterial blood It is not yet known whether this is due to mild concomitant emphysema gaseous alkalosis caused by the hyperventilation of heart failure with washing out of carbon dioxide or to actual interference with the transfer of oxygen in the lungs due to the chronic congestion

Clinical assessment of the degree of arterial desaturation is most unreliable even when the cyanosis is purely central in origin Different lighting skin pigmentation and circulation and many other factors will frequently deceive even the shrewdest eye If arterial desaturation is suspected then an arterial puncture should be done and precise values obtained. The use of oximeters or the analysis of capillary blood are not satisfactory and resorted to by those who are under the false impression that arterial puncture is painful and difficult

Let us now briefly consider the causes of central cyanosis due to the inadequate oxygenation of blood in the lungs In pulmonary emphysema the main cause of arterial desaturation at rest is the inefficient distribution of the inhaled air and of the mixed venous blood from the right heart *Many alveoli are still perfused with blood but* receive practically no additional fresh inspired air during normal respiration. Thus little oxygen can be added to the blood passing through them and the lung tissue is to all intents and purposes functionless The mixed venous blood passes through such lung tissue almost unchanged with the same effect as a right to left intracardiac shunt (venous admixture effect) Similarly certain parts of the emphysematous lung may still be adequately ventilated but receive little venous blood owing to the destruction and limitation of the pulmonary vascular bed in this disease This dead space effect will also render areas of lung quite functionless It is obvious that this cannot cause arterial desaturation directly as no blood flows through such lung tissue

However in very severe emphysema the combined effect of functionless lung due to impaired alveolar ventilation and to impaired alveolar circulation will leave such a small part of lung where blood and gas are efficiently brought together that when the patient exercises the limited blood-gas interface does not allow the adequate transfer of oxygen to balance the increased oxygen uptake and dramatic arterial desaturation (anoxaemia) will result Such patients are in a very similar position to a person who has suffered excessive lung resection as only a small part of the lung tissue is capable of maintaining efficient gas transfer between blood and alveolar gas

The ability to transfer oxygen from alveolar gas to blood is described in general terms as the diffusing capacity When a normal subject exercises the oxygen transfer *is increased*

y a number of mechanisms Increased ventilation raises the alveolar oxygen pressure and ie removal of greater quantities of oxygen from the circulating blood will also add to the ze of the diffusion gradient and resultant oxygen transfer in the lungs. It is also probable iat the pulmonary capillary bed expands considerably with increase in cardiac output id that the diffusing surface is further increased

If the arterial blood percentage saturation is studied in emphysematous subjects at st, the desaturation found is never of the extreme order seen in many cases of congenital eart disease with right to left shunt Figures below 85 per cent are unusual and even this gure is roughly equivalent to a 40 per cent shunt of unchanged blood This, no doubt, the main reason why marked polycythaemia, which would also contribute to cyanosis, unusual in pulmonary emphysema The arterial desaturation at rest is due to " venous lmixture " effect from underventilated alveoli and not to limitation of the diffusing pacity

It is of interest that polycythaemia is most marked in those emphysematous patients ith large hearts and right ventricular hypertrophy who are usually first seen in failure ving to an acute anoxic episode such as severe bronchitis, bronchopneumonia or status thmaticus Again it is possible, as already suggested, that these patients may have had fficient ventilatory capacity to allow considerable exertion and resultant anoxaemia over ng enough periods to stimulate excessive red cell production

Generalized lung fibrosis does not usually cause any marked anoxaemia, even on conderable exertion, unless emphysema is present as well Recently some exceptions to this ive been reported but it is not yet known whether this is due to alveolar underventilation to the reduction of effective lung tissue

There is another group of patients with generalized pathological infiltration of the lung ssue (some cases of Boeck's sarcoid, beryllium granuloma, neoplastic and granulomatous filtrations) who have pathological changes in the alveolar wall which interfere with the ormal diffusion of oxygen These patients often have efficient distribution of inspired r and mixed venous blood to all alveoli, and the ventilatory capacity is little impaired t rest most of these patients have normal or near-normal saturation of the arterial blood owever, they have no reserve diffusing capacity, and even moderate exertion will cause treme arterial desaturation despite an excellent ventilatory capacity Diseases destroyg large areas of lung (cystic disease, fibrocaseous cavitating tuberculosis, extensive onchiectasis) give a similar picture due to the very limited amount of functioning lung id the resultant decrease in diffusing capacity

Speaking in general terms, tuberculosis, excluding bronchial stenosis and pleural orosis, reduces both the circulation and ventilation of the diseased areas to a very similar egree, and such patients may have considerable lesions without any significant arterial saturation If there is definite cyanosis at rest then the disease is very extensive indeed there has been a recent event, such as a sudden spread, interfering with alveolar ventilation er a considerable area of lung

Finally, what help will arterial blood studies be in the selection and rejection of cases i lung resection ? This cannot be answered satisfactorily until more chest units carry it these studies before and after resection Yet, a number of important principles can e laid down Firstly the arterial saturation at rest is mainly a function of the efficiency gas distribution, whereas on exercise it is mainly a measure of the quantity of functioning ng and its diffusing capacity Distribution disturbances i e. alveolar underventilation, e rarely severe enough to threaten life except in acute respiratory infection or status thmaticus in emphysematous patients The greatest danger, from the point of view of

blood oxygenation is to leave a patient with a quite inadequate diffusing capacity For example if an emphysematous patient with a peripheral bronchial carcinoma and an adequate ventilatory reserve has some arterial desaturation at rest but this remains un altered on moderately severe exercise then this would indicate that although there is considerable venous admixture due to poorly ventilated alveoli, there is still a large amount of functioning lung with reasonable diffusing capacity Such a finding would weigh heavily in favour of the safety of resection

Bronchospirometry

It has long been the ambition of respiratory physiologists to be able to study the function of separate portions of the lungs Jacobaeus (1933) first showed that it was possible by means of a double-channelled bronchoscope with balloons to obtain satisfactory respiratory tracings showing the tidal air ventilatory volumes and oxygen uptake of each lung Gebauer (1939) and Zavod (1940) designed independently soft rubber catheters which rendered the procedure less unpleasant and traumatizing Further the resistance was less and the maximum respiratory excursion was closer to the vital capacity than when employing a bronchoscope

The resistance was however still excessive and Norris (1940) therefore evolved a single lumen catheter with a mask. One lung breathes through the catheter and the other round it into the mask Although this reduced respiratory resistance considerably it was not altogether satisfactory particularly as the resistance and dead space were different for each lung All these catheters had to be inserted under fluoroscopic vision Carlens (1949) has recently introduced a flexible double lumen soft rubber catheter The resistance of each channel is about one-fifth of that in a Zavod or Gebauer catheter Further a small rubber hook which is released by a thread when the larynx is passed engages the carina and ensures the correct placing of the catheter without fluoroscopy The considerably decreased resistance of this catheter as compared with other types also allows a moderate degree of exercise while the catheter is in place

Let us consider the meaning and value of the data obtained by this method The ventilation vital capacity and oxygen uptake of each lung can be expressed as a percentage of the total under these conditions The ratio of the oxygen uptake of the two lungs is an accurate measure of the relative blood flow through them As the patient is breathing high percentages of oxygen the blood flowing through the lung will be fully saturated no matter how poor the alveolar ventilation. Thus as the oxygen content of the blood entering each lung is the same and the blood leaving each lung is fully saturated the oxygen uptake of each lung will be a measure of blood flow through it In normal subjects the right lung usually has a ventilation oxygen uptake and vital capacity which is about 55 per cent of the total Occasionally this figure is even higher and in some cases the left lung may show about 55 per cent of total function Thus only figures of 40 per cent or below on either side can be considered really significant

If air is breathed and the expired gas collected on each side the oxygen uptake can be even more accurately determined However the simple application of Fick s principle is no longer valid as the oxygen uptake on each side is affected by the relative efficiency of gas distribution to alveoli as well as by blood flow Under these more natural gaseous conditions there may be vasoconstriction and decreased blood flow in underventilated lung There is a real possibility that the administration of oxygen may artificially increase the per centage of blood flow through an underventilated lung by eliminating such vasoconstriction

When bronchospirometry is performed it is usually in order to determine firstly the

function of diseased lung, which is to be collapsed or resected, and secondly, if possible, the function of the lung that will remain after operation The latter is the more important as the safety and the comfort of the patient will depend upon it Before considering how bronchospirometry will help answer these problems, it must be emphasized that such studies only measure the relative function of the two lungs at rest and in no way indicate the functional capacity and reserves of either lung A person with severe bilateral emphysema, if tested by this technique, would show oxygen uptake, ventilation and vital capacity of each lung to be within the normal limits Further, if one side developed severe bullae, then the percentage oxygen uptake and ventilation on the other side would increase well above the normal percentage Yet if the bullous lung were removed the patient would probably die of acute respiratory insufficiency

Returning to the consideration of the function of the more markedly diseased lung which is, if possible, to be collapsed or resected , in a number of instances (severe tuberculosis, bronchiectasis) the ventilation, oxygen uptake and vital capacity are negligible Only a small amount of air and blood enter the lung and it can be safely assumed that it is virtually functionless and that little alteration in the patient's status will result from its removal The fact that nearly 100 per cent of ventilation and oxygen uptake is carried out by the other lung does not prove that it is a healthy lung Nevertheless, its true functional capacity can be assessed adequately by studying the patient's exercise tolerance and ventilatory capacity Again the assumption that the remaining lung will function as well after the operation as before is only valid if the remaining lung is not injured or deformed

Unfortunately many cases under consideration are not so clear-cut as this If the diseased lung that is to be resected or collapsed shows 25–50 per cent of total function, then the clinician concerned still has a considerable problem It is often suggested that, on more marked exertion, the affected lung will not be able to continue to carry out such a high proportion of ventilation and oxygen uptake Such an attitude, and it is a reasonable one, may lead to resection in " border-line " cases It is very natural to want the organ which is to be removed to be relatively functionless However, Carlens (1950), using his new type of catheter, has been able to exercise patients considerably and obtain satisfactory tracings These experiments have shown remarkable constancy of the ratio of ventilation and oxygen uptake in all degrees of activity This is a very important observation and demands more realistic thinking It means that, despite the disease present, collapse or resection often demand a high price in terms of function and care must be taken that this price can be paid and that the remaining lung will have adequate function to make life tolerable

The prognostication of the functional capacity of the other lung after resection is very difficult and bronchospirometry will be of little help The history of previous disease in this lung, of asthma, or of chronic bronchitis with cough over a long period, will call for great caution The present ventilatory capacity can be studied and an estimate of the effect of the resection on this can be made, as previously described

Occasionally it is found that the diseased lung is carrying out more ventilation and oxygen uptake than the lung which appears to be healed or is now radiologically clear In such cases there is almost invariably a history of pleural disease Healed bronchial stenosis may give rise to a similar situation It has been shown by many investigators (Pinner, 1942) that so-called parenchymal disease, which may be quite extensive, frequently interferes but little with ventilation and oxygen uptake whereas old pleural disease (i e pneumothorax with fluid and long delay in re-expansion) *although showing little radiological abnormality* often causes gross impairment of ventilation and oxygen uptake It is in this type of case

where one lung has been diseased particularly with pleural involvement and now appears healthy and the other lung requires collapse at a later date that bronchospirometry is so valuable

It should be made clear that bronchospirometry is not necessary or feasible in all cases where resection or collapse are being considered It is only in those patients who have had bilateral disease or are suspected to have loss of function in the other lung due to a generalized lung disease such as emphysema that this procedure should be used Although bronchospirometry will not entirely solve the problem it will often give most valuable additional data The routine studies of ventilatory capacity ventilation during walking of the right heart and of arterial blood saturation should always be available Careful clinical examination and consideration of the patient s history and present respiratory function in everyday activities must never be forgotten as they remain of cardinal importance despite the increasing attempts to quantitate the patient s disability

Methods

Ventilatory Studies

(*a*) *Ventilatory capacity* An ordinary Benedict spirometer is usually employed to determine the maximum breathing capacity and a tracing is taken. The bell should be reasonably light and the spirometer well balanced with ball bearing suspension Resistance should be kept to a minimum and wide non-corrugated tubing used No canister or valve is necessary the rebreathing of air being advantageous as it prevents unpleasant symptoms due to the washing out of carbon dioxide A tracing can be obtained which gives a permanent record of the rate depth of breathing and of any rise in the respiratory level

The patient is told to breathe as much air as possible for fifteen seconds and can be allowed to choose his own rhythm providing it exceeds 70 respirations per minute An initial demonstration and several less violent practice runs are advisable Continual exhortation at the rhythm adopted imparts a sense of urgency and the need for maximal effort If possible the same observer and apparatus should be used for all cases as well as for the determination of the normal range

If hyperventilation causes violent coughing codeine can be given before further attempts are made Should the observer consider that the lung conditions are such that the unnatural and violent respirations may cause aspiration of actively infected material into healthy lung (i e large tuberculous cavity on one side being studied prior to thoracoplasty or resection) then the patient can be asked to take only three or four rapid and forced respirations using a high velocity tracing The ventilatory rate for each breath is measured in litres per minute The highest value should be recorded This gives values remarkably close to the maximum breathing capacity measured over 15 seconds The measurement should be in the erect posture

The maximum breathing capacity can also be measured with non return valves each side of the mouthpiece and by collecting the expired air in a Douglas bag It is most important that the valves used should have a reasonably low resistance even at very high rates of air flow This method is particularly useful when dealing with a mixed population of tuberculous and non tuberculous patients as only the mouthpiece and valves need be cleaned and sterilized as there is no rebreathing

(*b*) *Ventilatory demands* The measurement of the volumes being ventilated in any state of activity is very simple The patient wears a mouthpiece which is strapped round

the neck, and a nose-clip The mouthpiece is attached to a " box " with non-return valves, the expired air passing down a tube into a Douglas bag being held by the observer The subject breathes in and out to atmosphere until he is in a steady state and then switched to the Douglas bag and the expired air collected over a minute or more

The exercise can consist of walking at a standard speed up and down a corridor, or on a treadmill, with variable speed and inclination Baldwin, Cournand and Richards (1948) have devised a standard minute step test, in which, although the patient does not reach a steady state, the ventilation can be studied and compared with that obtained with normal subject. If the expired air is then diverted to a large collecting spirometer (Tissot), the ventilatory volumes can be studied during recovery The ventilatory volumes, especially when stated as a percentage of the maximum breathing capacity, that cause various degrees of dyspnoea can then be determined Another advantage of this test is that it is so short that even considerably disabled persons can carry it out satisfactorily Many investigators take the opportunity of studying the arterial blood saturation at rest and during, or after, exercise while performing these ventilatory studies An arterial needle is inserted into the brachial artery and secured more firmly with strapping If threaded properly (see below) this affords no difficulty even on severe exertion

Important references concerning this subject are Hermannsen (1933), Cournand and Richards (1941), Wright (1944), Baldwin, Cournand and Richards (1948), Warring (1949), Comroe (1950)

LUNG VOLUME DETERMINATION

The " closed circuit method ", measuring the dilution of an inert gas, is recommended, using Herrald and McMichael's (1939) important modifications These are, firstly, keeping the volume of the circuit constant by running in oxygen at the rate of uptake, and, secondly, the measuring of the rate and degree of dilution of the inert gas by means of a katharometer This instrument measures concentration by the change in the thermal conductivity of the gas in the circuit These workers used hydrogen but helium, which is safer, is now almost universally employed It was first suggested for this purpose by Meneely and Kaltreider (1941) The care and maintenance of the katharometer presents no difficulties and any normally intelligent person can be trained in this method in a very short time. There is some difficulty in obtaining the katharometer (Cambridge Instrument Co) and, if a Tissot spirometer (Siebe Gorman & Co Ltd) is available, then the oxygen wash out method of Darling, Cournand and Richards (1940) can be used It is a simple method and although, on theoretical grounds it has more errors, the results obtained are remarkably close to those obtained by other techniques Further, a Tissot spirometer is an essential piece of equipment for any good respiratory laboratory, as it is used for measuring volumes of gas rapidly and for collecting expired air to determine the oxygen uptake and respiratory quotient in all types of investigation (gas tension studies, cardiac output determinations, etc)

Important references in this subject are Christie (1932), Herrald and McMichael (1939), McMichael (1940), Darling, Cournand and Richards (1940), Fowler (A Review of Methods, 1950)

Study of the lung circulation and right ventricle

The advent of cardiac catheterization allows the precise study of right heart and pulmonary artery pressures Clinical examination, X-rays and fluoroscopy will give invaluable information concerning the size of the right ventricle This aspect is well

described in many standard text books dealing with heart disease Electrocardiographic studies of the right ventricle are now vastly improved in accuracy with the advent of the augmented unipolar limb leads and praecordial leads (Myers 1948 Johnson 1950)

The present paucity of knowledge concerning the right heart and pulmonary artery pressures in various lung diseases and after resection will continue so long as chest physicians consider this subject the province of the cardiologist Cardiologists are able to assess the state of the heart but are rarely able to relate this to the changes in the lungs and impairment of function Cournand s Hamburger Memorial Lecture (1950) is to be recommended for a review of this subject and gives the important references

Arterial blood studies

Arterial puncture This is described in some detail as there is little published information concerning the procedure The direct sampling of arterial blood is an important advance in respiratory physiology Although practised many years ago it is only recently that arterial blood sampling has become a frequent procedure in many centres It is quite amazing to what lengths some workers will go to avoid arterial puncture which with practice is painless and relatively easy The use of the indwelling needle (Cournand type or Riley modification) so that arterial blood can be sampled simultaneously with other gas and blood collection or even during exercise is also a great advance

The brachial artery should be used for this purpose for many reasons Patients are accustomed to venepuncture in this region and are not disturbed Femoral artery puncture causes greater apprehension and in any case the risk of damage to this artery is unjustifiable in view of the more critical blood supply of the lower limb in later life Furthermore vigorous exercise can be carried out without disturbing an indwelling arterial needle in the brachial artery

The artery should be carefully palpated as it lies medial to the biceps tendon and its course determined A small amount of novocaine is injected into the skin over the point of entry and more anaesthetic is injected down to and round the artery Large quantities are not necessary No attempt should be made to infiltrate the wall of the artery as this is almost impossible and quite unnecessary The arm is held supine and in extension there is no need for extreme extension unless there is considerable difficulty in entering the artery It is useless to attempt arterial puncture unless the artery is clearly felt With the left index and second finger fixing and marking the course of the artery the needle is inserted at the level of or just below the medial epicondyle Attempts to puncture the artery higher are often unsuccessful as the direction changes rather rapidly and variably

The stilette is removed from the needle and holding it by the flange it is inserted down towards the artery Entry into the lumen is at once appreciated by arterial spurting The stilette is then threaded down the needle taking care not to displace its point The blunt end of the stilette goes well past the point of the needle and passes along the lumen The whole needle can then be confidently threaded up the artery for a considerable distance until the flange of the needle tightens against the skin It is possible to thread the needle up the artery without the stilette but this is messy and may damage the intima The needle can then be strapped to the arm, although this is not absolutely necessary It can be left *in situ* for two to three hours and although not encouraged to do so the patient can flex his arm with considerably impunity

If the first attempt is not successful the needle should be withdrawn and a clean attempt made again from skin level after checking the course of the artery carefully It is

undesirable to " dig and delve " around the artery at depth and it is difficult to create a new " track " from an unsuccessful attempt

If, during anaesthesia or puncture, the patient should complain of tingling in the hand, the needle should be removed from the offending zone The author has never seen even a transient peripheral nerve disturbance after arterial puncture Very rarely, definite arterial spasm will be encountered after the needle has been inserted and the patient complains of " Raynaud-like " symptoms He can be reassured as this passes off in a few minutes

Haematoma is rare and usually caused by transfixing the artery unintentionally Most beginners go far too deep and would appear to believe that the brachial artery lies in the back of the arm

After removing the needle there is usually a brisk flow of blood for about a minute which is easily controlled by firm but not violent pressure The artery can be gently rolled under the fingers and in a short time, bleeding ceases and a dressing is not necessary Some rather apprehensive persons attempt to occlude the artery against the bone This is not only unnecessary but exceedingly painful and not without danger as it may cause syncope or cardiac irregularity, particularly in elderly patients with a tendency to cardiac arrhythmia

Respiratory studies are unusual in small children , if, however, an arterial blood sample is required, it is advisable to puncture the femoral artery, as entry into the brachial artery presents some difficulty

Collection and analysis of arterial blood The blood can be collected directly into a well-fitting syringe About 8–10 drops of heparin solution (10 mg /ml) are introduced before sampling and after rinsing it up and down the barrel to wet the walls the plunger is then pushed home so that only the small dead space contains heparin This is quite enough to prevent clotting of 10 c c of blood and avoids the inevitable bubble from the nozzle of the syringe The syringe usually fills without traction on the plunger If strong negative pressure is necessary the puncture is unsatisfactory and, in any case, will " pull " gases out of the blood If the syringe plunger is not too snug then it can be lubricated with a minimum amount of paraffin, but this should be avoided if possible A drop of mercury is introduced by dipping the end under mercury and drawing a small quantity into the blood After checking that there are no bubbles the syringe is then well sealed with an orange stick and then shaken to ensure mixing with the heparin

After sealing the syringe, the blood is anaerobically isolated and can be kept on a roller to prevent sedimentation Samples can then be transferred into pipettes for analysis when required It is hard to believe, but many workers still transfer this beautifully sealed blood to another vessel under paraffin oil Carbon dioxide can travel through paraffin to atmosphere at a high rate and this will greatly alter the gaseous properties and pH of the blood Further, it is a quite unnecessary extra manipulation, sedimentation of red cells occurs and efficient mixing and good representative sampling from under the oil is impossible If the blood cannot be analysed for a number of hours it is desirable to keep it in a refrigerator or an iced vessel, particularly in warm weather Under these conditions the red cells will sediment almost completely and at least two minutes' shaking is necessary before taking a sample for analysis

The determination of oxygen and carbon dioxide content is best carried out with the Van Slyke manometric apparatus (Peters and Van Slyke, 1932) This is by far the best method and is not technically difficult It is best to have two of these apparatuses working and all persons concerned should be able to use them It is wise to purchase the apparatus from a reputable firm and be advised by a worker in the field There are a number of

modified forms which are most unsatisfactory (shallow manometer curves unsatisfactory cocks incorrectly shaped chambers)

Blood gas tensions

Blood gas tensions can be directly determined by equilibrating a small bubble of alveolar gas with the blood in a modified Roughton Scholander syringe The gas bubble is analysed in an attached graduated capillary tube after equilibration Blood gas tensions are mainly studied by persons carrying out fundamental research It is a difficult technique (Riley 1945) and it is advisable to see the analysis being carried out by a trained person before attempting to set it up in a new unit A great deal of time has been wasted by ignoring this advice

Those interested in this aspect would be well advised to acquaint themselves with the literature on the subject It is not extensive Riley (1945) Riley (1946) Lilienthal (1946) Riley (1949) Riley (1951) Donald (1952)

Bronchospirometry

Bronchospirometry is best studied by watching a good team at work. The procedure is so near to the maximum of discomfort that a patient will reasonably tolerate that there must be no added unpleasant physical or psychological stimuli such as unnecessary noises coughing inexpert or careless manipulation or inadequate anaesthesia The spirometers and respiratory circuits should be on a trolley All apparatus must be carefully checked and in perfect working order before the patient comes in Low resistance valves and light canisters can be used The total circuit resistance can be reduced by using pumps in each circuit (Knipping) Satisfactory pumps are not easy to obtain

It is usual to carry out a preliminary bronchoscopy Ulceration of the trachea or left main bronchus is a contra indication to bronchial catheterization Deformities of the tracheo bronchial tree can be studied The finding of bronchial stenosis will greatly help in the interpretation of results and decisions concerning resection. Other contra indications to bronchospirometry are recent spread of tuberculosis pulmonary haemorrhage in the previous two weeks and recent laryngitis tracheitis or bronchitis Routine external spirometry is best carried out beforehand as these procedures are invaluable training for the patient apart from the important data they yield

The patient should also be screened and an initial estimation of the relative function of the two sides should be made and written down taking into consideration the history and clinical findings In this way invaluable experience is gained and errors of judgment long remembered

If the patient is producing a great deal of sputum an initial course of postural drainage should be carried out This allows more efficient anaesthesia and there is less chance of catheter blockage A sedative (amytal gr iij) should be given Some workers favour $\frac{1}{4}$–$\frac{1}{3}$ grain morphine sulphate half an hour before Large doses of morphia must be avoided The tongue fauces and pharynx are then anaesthetized by painting with 5 per cent cocaine hydrochloride A brush allows more precise and economic use of the anaesthetic The pyriform fossa and larynx are then anaesthetized and finally 1 c c of solution is injected with the patient leaning to the left and 0 5 c c with the patient leaning to the right Anaesthetization should be carried out slowly calmly and thoroughly It is imperative not to lose the patient s confidence and good anaesthesia is the key to successful bronchospirometry

There are several methods of introducing the catheter and a metal guide is usually provided However except with the Carlens catheter a guide is not necessary in properly

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CHAPTER 3

THE ASSESSMENT AND PREPARATION OF PATIENTS FOR MAJOR THORACIC OPERATIONS

Neither careful physiological estimates nor clinical impressions as yet provide accurate indications of the capacity of the patient to withstand major operations the new born baby of a few days tolerating such a serious operation as the repair of an oesophago tracheal fistula and the old man of 75 who survives an excision of the oesophagus indicate that age plays a relatively small part in selection. In fact the slowly metabolizing elderly patient may suffer less physiological upset than the active healthy adult and it is unwise to fix arbitrary standards such as those which exclude pneumonectomy for carcinoma of the lung in patients over 60 indeed the slower rate of tumour growth in that decade often provides the longest survivors The obese plethoric middle aged man is a more formidable risk than the very young or very old Children stand thoracotomy better than laparotomy and age itself is no bar to necessary interventions It may be wise to defer lobectomy for bronchiectasis until the child is old enough to co-operate intelligently with the physiotherapist and nursing staff in the pre- and post-operative stages but such a consideration does not weigh if the resection indicated is a total extirpation of the lung such a pneumonectomy may be indicated at the earliest age if total bronchiectasis or cystic disease is a menace to life or is delaying normal physical and mental development

The general condition

The psychological and physiological states are of obvious importance The combination of extreme nervousness with anoxaemia due to lung or cardio-vascular disease is often a deterrent to surgery unless there is considerable evidence that operative treatment will correct the underlying cause of the oxygen lack Renal disease may be a serious contra indication especially in operations such as oesophagectomy which may gravely disturb the protein and electrolyte balance of the blood Diabetes is no reason for excluding operations especially in pulmonary tuberculosis when the indication is for collapse or resection procedures as the dangers of coma and infection can be dealt with by insulin and antibiotic therapy the control of the tuberculous lesion often plays a great part in helping the diabetic treatment With the increased use of streptomycin many of the florid exudative lesions that develop in the diabetic show a tendency to fibrotic healing which may call for surgical help

Pre-operative preparation

Apart from the surgical treatment of tuberculous disease the patient who is to undergo major thoracic surgery should be in the ward for at least a week before operation Not only is bed rest of great value in patients with disordered thoracic function but the time is well spent in adjusting them to the atmosphere of a ward where much active pre and post-operative treatment is proceeding in a way not without its alarming effects to the newcomer ' From the earliest moment the quiet explanation of the basis and need for these measures is begun and represents the essential collaboration between nursing staff physiotherapists surgeon and anaesthetist

The clinical assessment

The history taking and clinical examination must be thorough and unhurried. This is the basis for diagnosis and provides the chief method of assessing the need or otherwise for operation, a surprising number of the histories are typical of the thoracic condition, note the frequency of repeated attacks of "pneumonia" in the patient with bronchiectasis and the persistent production of sputum, usually exaggerated after coryza, or the often heard story of "pneumonia" that improved with penicillin treatment and then relapsed (carcinoma of the bronchus!) Since diseases of the thorax may be the source of lesions elsewhere or because the thoracic viscera themselves may be secondarily invaded, the examination must follow the routines imposed in any medical ward the metastases of tumours or infections to the brain are specially indicative of the need for a neurological examination in detail in the patient with a suspected lung tumour, lung abscess or bronchiectasis

Patients with long-standing lung or pleural sepsis are naturally toxaemic So used may they be to chronic ill-health that many of them do not appreciate the handicap under which they have lived until the sepsis has been cured The attempt to obtain from them a history of ill-health, lassitude and loss of appetite may fail but the appearances are often typical, the state of the skin, the pallor, listlessness and apathy often confirm a picture of gross secondary anaemia proved by the blood examination Finger clubbing is often an indication of severe cardiac or pulmonary disease but has oddly escaped the attention of most patients themselves In chronic lung or pleural infection oedema of the posterior lower chest and of the lumber area is common, evidence of persistent hypoproteinaemia or cardiac failure

In some patients with peripheral lung carcinoma severe joint and bone pains (pulmonary osteoarthropathy) may be the presenting part of the clinical picture Occasionally pulmonary carcinoma may be responsible for neuropathies and peripheral neuritis in the absence of metastases

Amyloid disease

This is becoming increasingly rare but must be considered when patients with long-standing pleural sepsis are being assessed It is seen most usually in modern surgery when there is a tuberculous element to the infection, its victims being typically patients with a chronic secondarily infected tuberculous pyo-pneumothorax. Its detection is important, not because it should be regarded as an inevitably irreversible process but because the energetic treatment of its cause provides the only hope of reversal (Vernon Thompson)

In long continued suppuration with protein loss the amyloid glyco-protein is laid down in and replaces the connective tissue around the vessels and cells of the organ affected the spleen, liver and kidneys become increasingly bulky, their cell protein being slowly destroyed as a result of pressure atrophy by the infiltrating amyloidosis, other tissues and organs are affected including the lungs themselves The albumen content of the plasma falls with an increase in the plasma-globulin

The diagnosis depends largely on the suspicion that it may exist, the discovery of hepatic, splenic and renal enlargement in an advanced example of pulmonary tuberculosis especially with empyema would justify the diagnosis which is confirmed by biopsy Although liver biopsy is the most reliable way of providing a specimen showing the characteristic histological appearance, it is useful to remember that a positive microscopical diagnosis can often be made from study of small biopsies taken from the mucous membrane of the gums The urine will show albumen and hyaline casts.

The Congo red test depends on the absorption qualities of amyloid substance for this dye 15 c c of 0 75 per cent of freshly prepared aqueous solution of Congo red (the commercial type is dangerous for intravenous injection) is injected intravenously In amyloidosis the dye is quickly absorbed and so disappears from the circulating plasma in a healthy subject the dye can be detected in plasma samples as long as 10–12 hours after injection but in amyloid disease it is not found after an interval as short as 2–3 hours after infusion

Patients with a palpable liver, spleen and kidneys may tolerate major procedures such as pneumonectomy or thoracoplasty surprisingly well If the interventions control or remove the lung or pleural infection the visceral enlargements may recede The operation of pleuro pneumonectomy is preferable to staged thoracoplasties because it provides a method of rapidly removing the effects of a gross infection of lung and pleura

The radiological examination

This is the first essential after the history and clinical assessment if surgery is to be contemplated an up-to-date radiological survey must never be omitted If the patient is adjudged to be too ill for radiological examination he is certainly too ill to be taken to the theatre except for the immediate relief of acute tracheal or bronchial obstruction by bronchoscopy or the relief of a tension pneumothorax by needle aspiration. Thoracic operations should not be undertaken apart from the most severe emergency measures unless portable X ray photographs can be taken in the ward as the study of these provides the most important single measure in the post-operative control of the patient

In addition to plain radiographs fluoroscopy is of the greatest assistance and should only be omitted if the patient is too ill The study of the patient after the injection of contrast media into the bronchial tube (bronchography) pleural empyemata (pleurography) or into a vein or artery (angiocardiography) may provide essential and accurate information These auxiliary aids which should be regarded as part of the clinical examination are described elsewhere Tomography and kymography also have a place in diagnosis

Examination of the sputum

It may appear that this examination would be taken for granted but only too often information on this point is difficult to obtain The daily amount of sputum should be measured accurately and entered on the temperature chart the macroscopic nature of the sputum is of obvious importance especial note being taken of the presence of pus and blood Routinely the sputum is submitted to bacteriological and histological examination there is much to support this type of examination for at least six consecutive days if the aim is to exclude a tuberculous lesion The unexpected discovery of tubercle bacilli or of malignant cells is not a rare experience in a surgical thoracic ward

The discovery of tubercle bacilli in one odd isolated specimen should not be accepted too lightly as providing positive evidence of active pulmonary tuberculosis In children and patients who deny the existence of sputum the examination of the faeces for tubercle bacilli may be of great value and should be carried out before recourse is made to gastric lavage The examination of sputum obtained directly from the bronchi during bronchoscopic examination may detect tubercle bacilli or malignant cells

Examples exist where a false diagnosis of pulmonary tuberculosis has been made on the discovery of acid fast bacilli which in fact were timothy-grass bacilli particularly so may this error be made in those cases of lung infection due to tracheo bronchial aspirations of oesophageal contents in such states as cardiospasm (Barrett)

Haematological investigation

The value of a full knowledge of the blood picture, the haemoglobin percentage, the amount and particulars of the plasma proteins, and the blood grouping is obvious The frequent necessity for large blood transfusions in thoracic surgery calls for the most exact matching of blood and a knowledge of the rhesus factor The presence of polycythaemia with a high haemoglobin percentage in cyanosed congenital heart disease and in arterio-venous fistula of the lung indicates the need for saline solutions and not for blood transfusion during the operative phase, as these patients are subjected especially to the risks of thrombosis if they become dehydrated in the post-operative period

With the prevalent use of antibiotic therapy the services of a skilled bacteriologist able to assess the sensitivity or otherwise of the organisms under treatment are essential Blood culture examination, the cytological and bacteriological assessment of pleural fluids and exudates and the estimation of blood sedimentation rates are frequently required

Physiological investigations

The advantages and limitation of these methods have already been indicated They represent the field in which the greatest advances are possible and needed The information so obtained indicates the need to regard the cardio-respiratory system as one unit in most thoracic diseases as their interdependence is too obvious to require further comment The estimation of the vital capacity alone provides information of little value and the study of lung function, of the blood gases, of pressures in the great vessels, and the chambers of the heart are described in Chapters 2 and 16

BRONCHOSCOPY, OESOPHAGOSCOPY AND BRONCHOGRAPHY

These investigations provide information of supreme value They are almost free from danger and apart from children and very nervous patients are readily performed under local surface anaesthesia In addition to its diagnostic value bronchoscopy may be a life-saving measure when used for the aspiration of muco-pus or the removal of foreign bodies If the facilities and skill are not available for pre- and post-operative bronchoscopy there can be no justification for carrying out major thoracotomy

Technique of bronchoscopy

Anaesthesia Local anaesthesia has the great advantage of safety and rapid recovery so that the cough reflex is not abolished (a matter of considerable importance when pulmonary suppuration is present), and it assists in the technical ease of examination It may be carried out as an out-patient procedure, the patient being kept under observation for four to six hours after the bronchoscopy

Omnopon and scopolamine is injected at least one hour before the examination , the lips, tongue and gums are painted with a 10 per cent cocaine solution after preliminary tests for cocaine sensitivity In spite of its toxic effects cocaine is a more efficient local surface anaesthetic than amethocaine preparations, but these are adequate

The tongue is held forwards so that its dorsum, the palate, the uvula and the posterior pharyngeal wall can be painted thoroughly by means of a brush or of wool swabs held in a special forceps of which Brock's model is excellent This step should be deliberate and slow, the patient being encouraged to breathe a little more deeply than usual as this diminishes the tendency to retch when the sensitive pharyngeal wall is painted After a

pause the curved forceps holding a wool swab soaked in the surface anaesthetic is passed down each side of the back of the tongue in turn to reach the *pyriform sinus* here the anaesthetic solution will soon anaesthetize the mucous membrane and the superior laryngeal nerve which lies just beneath it on the medial wall of the sinus The curved applicator is then held against the epiglottis When this has been anaesthetized a direct laryngoscope of the Magill type enables a view of the interior of the larynx to be obtained and a wool swab can be introduced into the glottis or 2 c c of 10 per cent cocaine can be run into the larynx through a laryngeal syringe This is probably preferable to the injection of the same amount through a crico thyroid puncture into the larynx

General anaesthesia When indicated this is best done under pentothal and curare this requires the services of a skilled anaesthetist The dosage of course should be sufficient

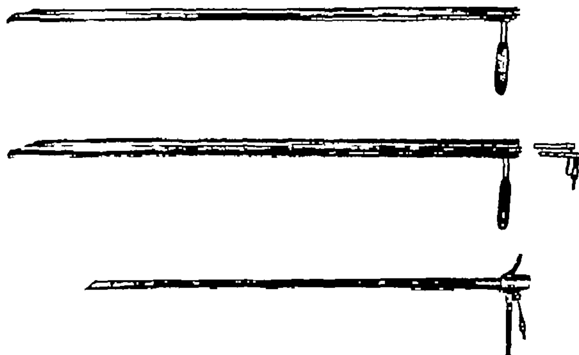


Fig 3 1 —The two upper instruments represent the oval Negus bronchoscope with proximal lighting The lower instrument is that of the more circular Chevalier Jackson broncho-scope which is provided with distal lighting.

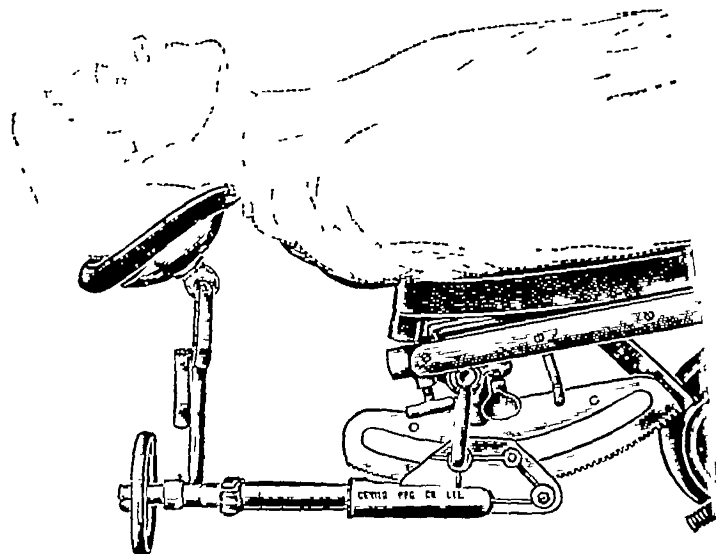
to obtain rapid laryngeal relaxation but an apparatus to provide oxygen under pressure and an efficient sucker must be in complete readiness before the pentothal and curare are injected intravenously As soon as anaesthesia and relaxation have been achieved a few breaths of oxygen under pressure should be administered, as in controlled respiration through a tight fitting face piece before the bronchoscope is passed

The passing of the bronchoscope Special head rests are made and help in the ease of examination

The bronchoscope can be readily passed with the patient sitting up (Fig 3 3) this is most useful as a post-operative measure in the treatment of a collapsed lobe whose bronchus is occluded by muco pus A comfortable position for patient and operator is with the patient lying flat on the back with the shoulders partly over the edge of the table with an assistant supporting the head if a special rest is not in use or available

Whatever the position of the patient and whether a head rest or not is in use the

essential point is to have the head extended so that the occiput is well back and in such a position that the mouth and trachea are in a continuous straight line As soon as the



[Genito urinary Mfg Co

FIG 3 2 —Bronchoscopy position



FIG 3 3 —Bronchoscopy and bronchoscopic suction in the ward for post operative lung collapse
A photograph taken during the course of an emergency bronchoscopy

bronchoscope is in the trachea, the head can be altered in position and the occiput is brought forward a little and the head moved from side to side

The bronchoscope can be passed directly into the larynx without first introducing a laryngoscope large enough to allow the passage of the larger instrument through it With

the tongue held forward a little by the left hand the bronchoscope is passed until the epiglottis is seen this is gently displaced forwards by the tip of the bronchoscope which is then passed onwards through the glottis and cords If the surface anaesthesia has been adequate this is easy and painless

Points to note in the bronchoscopic examination

The cords and trachea are examined closely for evidence of diseases (inflammatory or neoplastic) and laryngeal nerve paralysis especially important is this in suspected carcinoma of the bronchus as paralysis of one vocal cord and tracheal involvement by upward spread of the tumour may indicate inoperability

The carina is studied carefully it is usually sharp and clear in malignant disease of the lung it may be rounded and broad as the result of malignant invasion and enlargement of the inferior tracheo bronchial lymphatic glands

The right bronchus The opening of the right upper lobe bronchus is easily seen if the head is held well over to the left side it appears as a rather oval opening below the carina A better view of the interior of this bronchus is obtained by looking with a right-angled telescope and the commencement of the subdivisions can be made out (Fig 3 4)

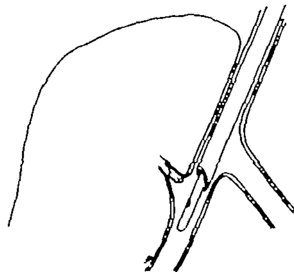


Fig 3·4 —Diagram of a right-angled telescope viewing a tumour in the right upper lobe bronchus

As the instrument is advanced down the right bronchial stem the middle lobe bronchial orifice will be seen about 1 cm. below the upper lobe orifice and leading out of the front wall of the stem almost directly upwards or anteriorly Usually opposite to this at a slightly lower level will be seen the opening of the bronchus into the apical segment (dorsal lobe) of the lower lobe a little further down there is no difficulty in studying the openings of the three basal segmental bronchi

The left bronchus This is not so easy to study as the right one because of its greater obliquity but if the head is held well to the right its upper lobe orifice and the segmental bronchial openings of the apical and basal segments of the left lower lobe are readily seen It is not possible usually to see the lingular bronchial orifice but the carina between the apical and anterior segment of the upper lobe can be seen through the right angled telescope

Complications of bronchoscopy

Trauma to teeth Wherever possible pre-operative dental care will have been carried out to include the removal of carious teeth and the scaling away of dental aggregations loose teeth in the upper jaw are particularly liable to dislodgement and bronchoscopy in the presence of gross paradental sepsis might carry infection into the bronchus

Laryngeal trauma This should not follow It is possible if the local anaesthetization is inadequate or too large an instrument is passed in children The *post-operative effects* may be a mild traumatic laryngitis or a considerable stridor the latter may be due to oedema actual cord injury or mucosal sloughs In children the stridor is accompanied by cyanosis a fast pulse and rib recession The immediate treatment is by steam bottles and an oxygen tent But if the condition does not improve rapidly steps must be taken

to do a low tracheotomy. The necessity for this may arise after bronchoscopy in infants when foreign bodies have been removed The problem in a children's hospital is gravely complicated at times when patients are seen in whom abortive attempts to remove foreign bodies in the bronchi have caused not only severe laryngeal oedema but have failed to relieve the collapse of the lung or lobe beyond the obstruction In such, early attempts should be made to secure the foreign body through a bronchoscope and this may require tracheotomy immediately afterwards at the same operation *

Haemorrhage A little bleeding is common after biopsy specimens have been taken from vascular tumours, its occurrence is one of the arguments in favour of the use of local anaesthesia, as its chief danger is represented by a flooding of the bronchial tree by blood in the absence of an efficient cough reflex If noted at the time of the biopsy, the blood should be aspirated by means of a powerful sucker and direct pressure applied by means of a large swab held in special probes

Occasionally severe haemorrhage follows of which a few accounts of a fatal nature have been published: these were chiefly in instances of biopsy done near the left upper lobe bronchus and in the region of the right middle bronchus. If a tumour is seen or suspected in the left upper lobe bronchus great care is necessary not to include a portion of that bronchus in the biopsy forceps, as the pulmonary artery is close to it as it sweeps behind the upper lobe bronchus Similarly the middle lobe artery is close to the origin of the segmental bronchus to that lobe and may be torn if the biopsy bite is too deep

If bleeding is tending to be uncontrollable as a last resort a Thompson blocker should be inserted rapidly to prevent the spill over of blood into the other bronchus

It remains to point out the obvious danger of bronchoscopy in patients with aneurysms of the aorta that may be pointing into the bronchus. the pre-operative diagnosis of these may be that of bronchial carcinoma and the possibility of such a diagnostic error should be kept in mind As an extreme rarity an aneurysm of a patent ductus arteriosus may erode the left main bronchus but the clinical diagnosis of a patency will usually not have been difficult though again it is well to remember that aneurysmal dilatation of the ductus Botalli has been regarded as a mediastinal or lung tumour

OESOPHAGOSCOPY

The investigation and treatment of diseases of the oesophagus requires endoscopic examination as a routine measure and a surgeon unequipped for oesophagoscopy should not undertake the surgical care of carcinoma, oesophagitis or cardiospasm The diagnostic confusions so frequent in these three diseases if opinions are established only on radiological appearances, can be avoided if oesophagoscopy and endoscopic biopsies are employed In the treatment of peptic ulcer of the oesophagus, cardiospasm and fibrous stricture, satisfactory relief can often be obtained by oesophagoscopic dilatations The examination is simple, safe and provides reliable evidence: the patient undergoing it need not be retained in hospital

Technique of oesophagoscopy

Anaesthesia As in bronchoscopy local surface anaesthesia carries great advantages, being safe and effective · for certain manipulations in which the larger type of oesophagoscope is used. anaesthesia by pentothal and curare is valuable

* I have had to perform tracheotomy once in a child three days after lobectomy for bronchiectasis At the operation a large slough of the tracheal mucous membrane was removed this had probably resulted from the use of too large an endotracheal tube during the anaesthesia

Food and fluids are forbidden for at least six hours before the examination An hour before the operation omnopon and scopolamine are given and half an hour later the patient is given a lozenge of amethocaine hydrochloride to suck The surface anaesthesia used is a 2 per cent solution of amethocaine which is preferred to cocaine which might be swallowed The lips tongue palate and upper pharynx are sprayed or painted with the solution the tonsils epiglottis and pyriform fossae are best anaesthetized by direct pressure of a swab soaked in amethocaine held in curved application forceps

Inhalation or basal anaesthesia is dangerous in patients with oesophageal obstruction because of the risk of tracheal inhalation during the induction The risks of this may be lessened if the patient is anaesthetized with the head and chest well propped up and if the oesophagoscope is introduced rapidly so that retained oesophageal contents can be aspirated quickly through a large-bore aspirating tube attached to a powerful sucker a cuffed intratracheal tube can be employed but the presence of this hampers the easy passage of the oesophagoscope

Position of the patient As in the case of bronchoscopy a special head rest may be employed but is not essential and I prefer to have the head held. With either method the head and shoulders must be well clear of the edge of the table so that the upper half of the scapula just reaches to that point The neck should be in front of the plane of the body with the head flexed backwards at the occipito-atlantal joint

Two instruments are in common use the smaller circular Chevalier Jackson oesophagoscope with distal lighting and the larger oval pattern of Negus which has proximal lighting and allows more room for good visualization and instrumentation of the oesophagus Because of its greater bulk it is more difficult to pass than the Jackson type but with good local anaesthesia and a co-operative patient this can be overcome Its use is valuable if hydrostatic dilatation of the spastic area of the oesophagus in cardiospasm or the placing of a Souttar s tube is to be carried out

Passage of the oesophagoscope The upper teeth and lip are protected by the left hand a full view of the epiglottis must be obtained before any attempt is made to negotiate the upper sphincter of the oesophagus (the crico pharyngeus muscle) which lies behind the cricoid cartilage The tip of the instrument is gently lifted forward to engage the anterior wall of the oesophageal entrance and the right hand exerts gentle pressure until the sphincter gives The direction of the force should be anteriorly so that the cricoid cartilage is lifted forwards if this is not done with the greatest care the instrument will tend to press against the posterior pharyngeal wall which is vulnerable as it lies rigidly against the front of the bodies of the cervical vertebrae It is in this posterior wall that most of the recorded tears have been reported As soon as the crico pharyngeus muscle has been passed the lumen of the oesophagus usually containing a little frothy fluid is easily visible

If the upper opening of the oesophagus appears small and difficult to enter a small gum elastic oesophageal bougie is passed through it and the oesophagoscope is passed along the line so indicated Throughout the further downward passage of the instrument a clear view must be obtained and for this good lighting of the instrument and the use of an efficient sucker is essential

When the instrument is beyond the level of the aortic arch the head is allowed to drop down and to the right As soon as the instrument has passed through the cardia gastric juice flows back into its lumen Under local anaesthesia the pinch-cock mechanism of the right diaphragmatic crus can be studied easily the contractions of the muscle fibres during each inspiration being readily seen and its efficiency or insufficiency noted (see hiatus hernia Chapter 26)

The abnormal conditions that may be studied are described in the section on diseases of the oesophagus and of the diaphragm (p 418) It would be pedantic and unnecessary to say today that all foreign bodies should be removed by the oesophagoscope as soon as possible to avoid any dangers of ulceration with the sequel of mediastinitis

The complication of rupture of the oesophagus during endoscopy

With care this should never occur If the instrument is forced clumsily in the region of the crico-pharyngeus the thin rigid posterior wall of the pharynx may split Tears of the oesophagus itself in its thoracic portion have been described above strictured areas or through portions of the wall of the gullet infiltrated by carcinoma

Recognition of a tear should be obvious at once if it includes the posterior pharyngeal wall If this is not so, the symptoms will be those of pneumothorax if the instrument has passed through into the pleural cavity or a widespread emphysema first noted above the sternum and clavicles will be evident Infection of the mediastinal tissue will rapidly supervene if immediate operative repair has not been carried out or if the accident has not been suspected Quite exceptionally a tear may not manifest itself for several days, when the signs and symptoms will be those of mediastinal abscess,* empyema or emphysema

Treatment of accidental perforation

If during the course of oesophagoscopy or gastroscopy the pharyngeal or oesophageal wall is torn the only treatment that can be recommended is immediate operative exposure If the oesophagoscope has torn the posterior pharyngeal wall this should be repaired through a wide cervical exposure, as in the operation for removal of a hypo-pharyngeal diverticulum (see p 433) The rent is repaired in two layers by interrupted sutures and the peri-oesophageal area drained If the radiograph discloses a pneumothorax the air should be withdrawn completely after the oesophageal rent has been closed, or a closed water-tight drainage established pleural drainage is probably not necessary if the tear is treated within six hours The patient is given full doses of penicillin parenterally Perforations in the thoracic oesophagus, whether they be traumatic or spontaneous (Barrett, 1946), should be treated by immediate thoracotomy and repair, often accompanied by a temporary gastrostomy and closed pleural drainage These perforations are almost invariably into one or other pleural cavity and cause pain in the abdomen and chest with a rapid onset of pyrexia due to mediastinal infection With surgical treatment and antibiotic therapy they have an excellent chance of survival (see p 456)

PHYSIOTHERAPY

The use of physiotherapy will do much to improve the general health of the patient, increase vital capacity and reduce the amount of purulent bronchial secretions before operation In the post-operative phase continuance of such measures will only be possible if the patient has full confidence in the methods that have been taught him before operation and if he co-operates in the matter of correct posture, active functional movements of the diaphragm, chest wall and the accessory muscles of respiration and the efficient expectoration of bronchial secretions The more efficient the physiotherapy the less frequent will be the need for post-operative bronchoscopic suction for the correction of atelectasis

* I have seen a mediastinal abscess pointing at the level of the seventh thoracic vertebra which followed a gastroscopy the patient recovered after drainage and antibiotic therapy

The methods adopted are applicable to the ward as a whole but individual attention to each patient is also essential The surgeon should discuss each individual patient with the physiotherapist and rigid routines are unwise A patient with unilateral pulmonary

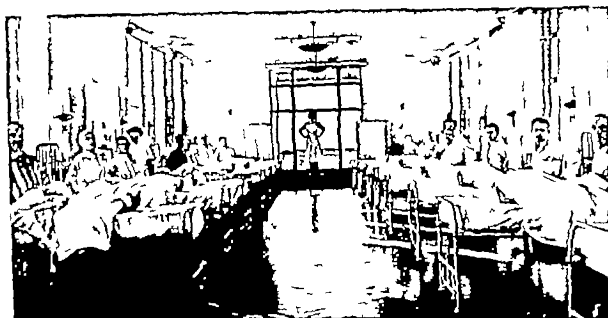


FIG 3 5—General ward exercises to pre- and post-operative patients. (Queen Elizabeth Hospital, Birmingham)

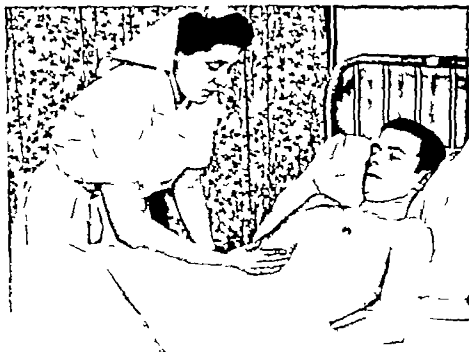


FIG 3·6—Unilateral breathing being taught

tuberculosis who is to undergo thoracoplasty or resection may need unilateral breathing exercises confined to the sound side and a good physiotherapist can achieve this without breaking the rule of local rest applied to the lung affected by the disease Patients with carcinoma of the oesophagus with severe malnutrition often have little capacity for vigorous

exercises suitable foi a young adolescent with bronchiectasis, and the regime for e patient is arrived at by joint consultation

Physiotherapy being a profession in itself iequiring a long training in study ε technique, it is not possible for a surgical writer to do justice to the subject and the outl given below is intended for the guidance of physicians and surgeons who aie peih unacquainted with the value of this thoracic treatment

Bronchiectasis and lung abscess

At least a week (preferably more) should be spent on pre-operative treatment in t ward if the amount of sputum has not been decreased to manageable proportions operati should be delayed until this has been achieved The pre-operative plan includes postu drainage, breathing exercises, the correction of deformities (thoracic and spinal) and gene *exercises*

Postural drainage Although bronchiectasis is usually a basal disease the advice th

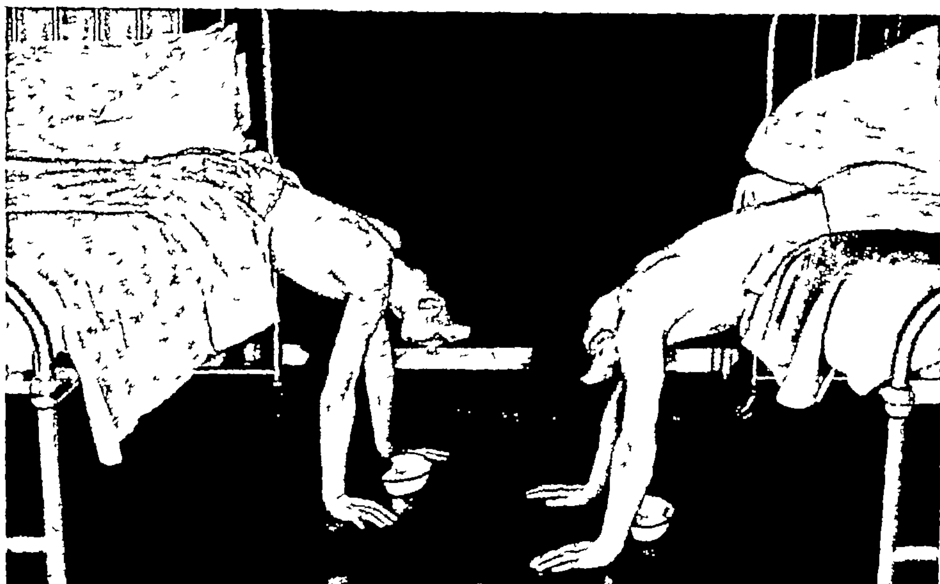


Fig 3 7—Thoroughly unsatisfactory positions for postural drainage
Such are exhausting and only drain part of the lungs

the patient should lean over the bed twice a day is quite futile Fig 3 7 illustrates a ba type of postuial drainage it fails to drain all the lowei lobe segments and is ineffectiv in the emptying of seciétions from the right middle lobe and the upper lobes , the positio is uncomfortable and exhausting to ill patients In most patients with bionchiectasis th moistness of the various segments cannot be related entirely to bronchogiaphic appearances in children especially it is important to drain posturally every segment and this can b achieved by using the different positions shown in Fig 3 8

If the physiotherapist encourages active coughing and employs light percussion afte each position has been adopted for a few minutes, the bronchial passages aie moie effectivel cleared than by long wearying periods spent in one position over wedges or on specia postural drainage beds Such devices tend to encourage the adoption of uniform unimagina tive routines, being too passive and extremely dull for the patients Obviously the segment containing the bionchiectasis or the lung abscess will call foi the most caieful and pro longed drainage. At no time should the patient be exhausted by too vigorous a iegime

constant encouragement and explanation together with his own observations on the daily decrease in the amount of sputum will soon indicate that the treatment is worth while

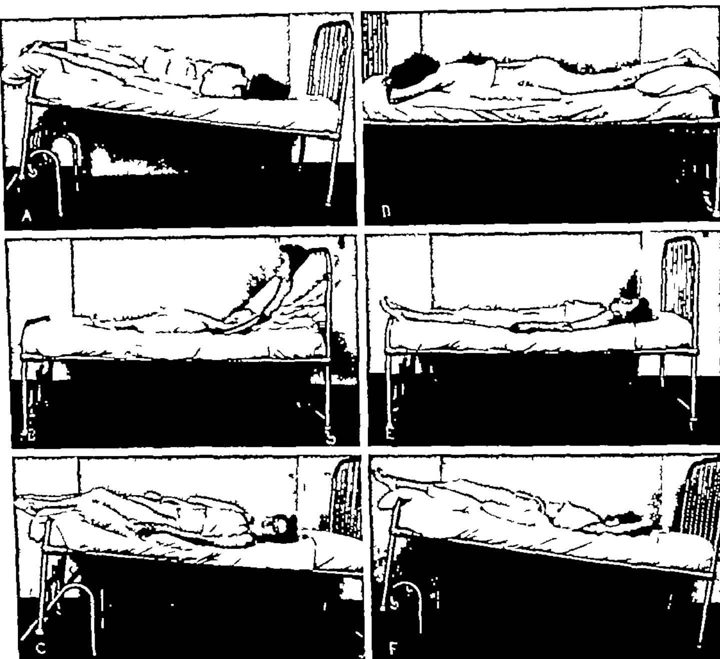


FIG 3 8 —Positions for postural drainage of individual segments.

(A) Left lateral and posterior basal segments.
(B) Apical segments of upper lobes.
(C) Right middle lobe
(D) Apical segments of lower lobes.
(E) Anterior (pectoral) segments of both upper lobes.
(F) Anterior parts of both lower lobes.

Breathing exercises Most thoracic surgical patients have diminished chest movements in all areas and not those confined to the area of disease frequently they have unconsciously adopted the habit of shallow breathing as this decreases the tendency to cough The diaphragm rarely descends to its full unimpaired degree Ventilating movements are



(*a*)



(*b*)



(*c*)



(*d*)

FIG 3 9

(*a*) and (*b*) Chest exercises

(*a*) Inspiration, (*b*) Expiration

(*c*) and (*d*) Upper chest exercises

(*c*) Inspiration, (*d*) Expiration

especially poor in patients who have been confined to bed for long periods The aim in the pre-operative period is to encourage full movements of the areas of the chest most affected by disease to teach the value of diaphragmatic contraction and relaxation to correct postural deformities and to increase the venous return to the heart

Most patients have great difficulty at first in learning to aerate fully the bases of the lungs because they have relied for a long time on upper respiratory movements The physiotherapist therefore starts by teaching diaphragmatic control. The next phase is to teach the patient to ventilate and empty as far as possible the different areas of the lung Coughing in the nature of convulsive exaggerated movements must be avoided many patients tend to force the chest forwards or laterally by active spinal column movements which are of course quite ineffective though giving the uninitiated patient the feeling that he is moving mountains of air! This type of error can best be eliminated if the technique of *pressure expansion exercises* (see Fig 3 9) is followed by breathing against moderate pressure provided first by the physiotherapist s hands and then by his own the patient can estimate and appreciate the effects of his own breathing efforts and will soon learn the need for concentration during the various manœuvres of breathing required Direct pressure can steady weak or painful areas while the breathing areas to be inflated are under attention Throughout this exercise the patient should be in a comfortable position far removed from the regimented posture of the old Fowler position

Under good tuition the co-operative patient soon learns to control his breathing so that at will he can ventilate a lung or single lobe more fully than their counterparts sited elsewhere this is of special value in pulmonary tuberculosis where increased movements of the diseased side or lobe may be undesirable The combination of postural drainage and of breathing exercises not only improves the general condition pre-operatively but the patient educated in their use will continue them in the post-operative period when they assume an even greater value

PRE OPERATIVE CHEMOTHERAPY

The principles of asepsis and antisepsis of careful technique with the avoidance of haematoma formation and the prevention of widespread contamination when septic organs such as the oesophagus or bronchus are opened by preliminary skin sterilization the use of skin towels and all the customary aids to careful precise operating govern all surgical procedures The adoption of pre-operative antibiotic therapy in thoracic operations is directed chiefly against the pathogenic organisms universally harboured by the respiratory and pro-pharyngeal passages Penicillin injections are given for 24 hours before most surgical interventions and continued in the post-operative period In operations on the heart or great vessels this period should be lengthened to 48 hours as every measure possible should be taken to limit any risk of bacterial endocarditis Antibiotic therapy in lung abscess pulmonary tuberculosis and subacute bacterial endocarditis has a far wider place than mere pre-operative use

Penicillin Inhalations

Before operations for bronchiectasis and lung abscess penicillin inhalations gi through an efficient inhaler are of some value in ridding the bronchial tree of many pyoge organisms The mucous membrane of the bronchi and pharynx absorb penicillin sufficien to provide a reasonable blood level of the substance Before operations on the oesophag

or for the removal of pharyngeal diverticula the inhalations may be supplemented by the sucking of penicillin pastilles and by the use of streptomycin gargles that are swallowed, as this may destroy organisms not sensitive to penicillin

Antibiotics such as penicillin, aureomycin and streptomycin in the pre-operative, operative and post-operative phases have greatly decreased the incidence of pleural infection after major thoracic operations for infection of the lung or pleura The general acceptance of this calls for no prolonged arguments on the value of antibiotics but their undoubted efficiency is no argument for the abandonment of scrupulous surgical techniques that are the safest prophylaxis against post-operative sepsis Indiscriminate use of antibiotics is wasteful and may cause unnecessary discomfort to the patients because of the many injections required The choice of effective antibiotic agents can be largely made on the bacteriological study of sensitivity or resistance and with the wide range of substances such as streptomycin, aureomycin and chloromycetin this control has become increasingly important

Pre-operative nutritional requirements

Many thoracic patients apart from those with obstinate lesions of the oesophagus are badly nourished often as the result of chronic sepsis and many are in a negative nitrogen balance phase with the characteristic features of hypoproteinaemia The measures adopted for the correct nutrition of surgical patients are discussed in Chapter 5

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CHAPTER 4

OPERATIVE TECHNIQUE

ANAESTHESIA

The physiological principles underlying the different methods of modern thoracic anaesthesia demand co-operation between surgeon and anaesthetist and a sympathetic understanding of each other's problems If the surgeon wishes for the absolute quiet of controlled respiration during the operation he must be prepared for occasional pauses when the anaesthetist is sucking clear a bronchus obstructed by sputum. At some stages the anaesthetist must be allowed sole control of the patient when surgical manipulations should cease so that a patient on the verge of dangerous collapse from cardiac or respiratory embarrassments can be resuscitated

To provide appropriate anaesthesia at all stages of an operation the anaesthetist must have an adequate understanding of respiratory physiology and a wide appreciation of the surgical techniques This is particularly obvious in cardiac operations such as the surgery of pulmonic or mitral stenosis where there must be a free interchange of information at all stages of the operation. During intrathoracic operations as far as possible the lungs must be kept inflated and atelectasis with its characteristic dusky blue appearances should not be allowed The inflated lung can be kept out of the operative field by the gentle pressure of lung retractors held against the lung which is covered in a moist saline mop Whenever possible the anaesthetist should fully re-aerate the lung periodically This is essential in operations on cyanosed patients and during lengthy operations such as oesophagectomy or total gastrectomy The use of a large intratracheal tube provides the safest method of control alternatively if full relaxation of the larynx by curare or muscle relaxants is maintained the pharynx can be packed off and the inflation carried out by a tight fitting mask This latter method is not used in the presence of copious bronchial secretions when intermittent suction is easier through a large intratracheal tube

Anaesthetic agents

During extensive thoracic operations the maintenance of adequate cardio-respiratory function is more important than the actual selection of the anaesthetic agents though the two problems are often intimately combined cyclopropane has decreased in popularity because of the narrow margin between light and deep anaesthesia its tendency to slow unduly the pulse rate or cause cardiac irregularities and because it is highly explosive The surgeon used to diathermy often feels its lack when working within the pleural cavity in a patient under cyclopropane or other Controlled respiration with the patient anaesthetized by pentothal and relaxed by a curare-like substance allows oxygen to be given in large quantities at an adequate tension and is increasingly used with nitrous oxide

Ether with oxygen is of value in cardiac operations and has not the irritant effects often attributed to it if administered smoothly and in carefully graduated dosage but it reduces cardiac output and has a toxic effect on the solid viscera Chloroform is inadvisable because of its toxic effect on the heart and solid viscera such as the liver and kidneys

Trilene is contra-indicated because when used in a closed circuit it produces a rapid rate of breathing, occasionally has unpleasant neurological effects, and is a liver poison

Whatever anaesthetic agents are used a rapid post-operative recovery should follow so that the patient has a cough reflex before return to the ward

Intravenous procaine may help in steadying the heart during direct cardiac operations or when the pericardium is opened as in intrapericardial pneumonectomy for carcinoma of the lung Given intravenously procaine is far more effective than after simple topical application It has, however, the grave disadvantage that it may seriously lower the blood pressure It is possible that quinidine started pre-operatively may diminish cardiac irregularities more safely

Physiology of the open thorax under anaesthesia

Increased knowledge of the physiology of open pneumothorax has simplified anaesthesia though its administration may require complicated apparatus and techniques The days of unmeasured positive pressure anaesthesia and of operation in negative pressure boxes and theatres have long since gone The maintenance of quiet respiratory movements which not only permits deliberate, unhurried surgery, but provides the maximum respiratory safety by the prevention of paradoxical breathing, is achieved by adequate lung ventilation and efficient gaseous interchange allowing full oxygen intake and carbon dioxide absorption in a closed circuit, in which the pressure of the gases flowing to the lung is under the direct control of the anaesthetist

Effects of an open pneumothorax

Under the influence of normal atmospheric pressure the lung on the open side will collapse if the lung inflation is not under the anaesthetist's control, the mediastinum will be dragged over to the " sound " side when that lung inspires and be pushed back towards the open pleural cavity during expiration Furthermore, a considerable quantity of tidal air will pass to and fro from the bronchus of one side to that of the other (" paradoxical breathing ") Inevitably a rising tide of carbon dioxide will develop, the consequent rise in carbon dioxide tension in the blood stimulating the respiratory centre of the medulla with resultant increase in the amplitude and frequency of breathing This exaggerated breathing accentuates the violence of the mediastinal movements and quite apart from the anoxaemia and hypercarbia of the whole body this flapping hinders the venous return through the thin-walled vessels leading to both auricles, so causing a grave circulatory failure with all the obvious signs The anaesthetist therefore takes measures to prevent (1) exaggerated respiratory and mediastinal movements, (2) anoxaemia, (3) an increase in the blood carbon dioxide and (4) the shunt of tidal air from one lung to the other It is the exaggerated mediastinal movements, the paradoxical breathing and rising tide of carbon dioxide in the blood that cause asphyxia and not the collapse of the lung on the open side

Controlled or assisted respiration

This method of artificial respiration achieves the desired control better than any other Essentially it requires a closed or to and fro circuit in which the anaesthetic agent and oxygen are administered while the exhaled carbon dioxide is absorbed in a canister containing soda lime attached to the circuit The respiratory centre is depressed by the pre-operative drugs such as morphine and thiopentone, by the anaesthetic (cyclopropane has a specially depressant effect) by the carbon dioxide absorption and the high oxygen content of the blood The lungs are artificially inflated by intermittent manual pressure on the re-breathing

bag or by the use of machines such as the spiropulsator of Crafoord or Mushin In this country most anaesthetists prefer manual compression of a rubber bag as this is more sensitive and the degree of inflation or deflation of the lungs can be altered more quietly At certain stages of the operation where the technical requirements demand it complete cessation of active respiration movements can be obtained the ventilation of the lungs being artificially maintained The mediastinum is steadied paradoxical breathing stopped the blood carbon dioxide is left at reasonable limits and a high oxygen ventilation is provided

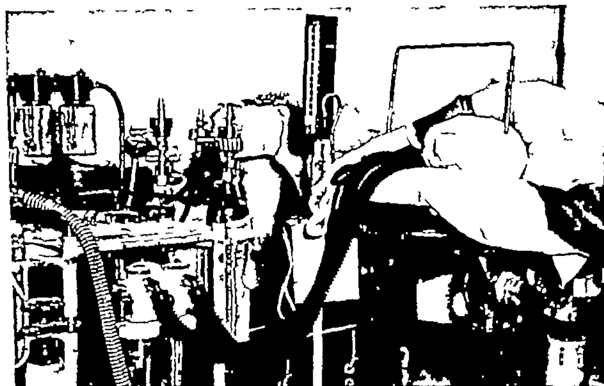


Fig 4 1 —Patient in position for a right thoracotomy

The intratracheal tube is in position and is connected to Mushin apparatus for the passage of oxygen and anaesthetic gases and for the absorption of carbon dioxide

The alternative method of allowing normal breathing to continue against a positive pressure obtained by inflation of the lungs with oxygen and the anaesthetic agent delivered through a tightly fitting mouth piece or through an intratracheal tube has several serious disadvantages It has been shown by Crafoord and others that this method is especially inefficient with regard to carbon dioxide elimination the blood CO_2 may steadily mount even in the absence of clinical cyanosis which is prevented by the high oxygen delivery and uptake and the absence of hyperpnoea which is stopped by the depth of anaesthesia produced by cyclopropane and ether During the operation this hypercarbia may produce a slow pulse rate and high blood pressure which after the anaesthesia has been discontinued is replaced by a marked fall associated with shallow breathing

Anoxia during thoracic operations

The anaesthetist may have to correct or prevent any one of the four types of *anoxia* Thoracic patients with extensive lung disease or congenital cardiac defects may come to the theatre with anoxia and the whole aim is to prevent further oxygen depletion The

actual administration of the anaesthetic with large quantities of oxygen delivered patient whose basal metabolism has been lowered by muscular relaxation may explai improvement in colour often seen when congenital cardiac patients with pulmonic ste are anaesthetized, although these patients pre-operatively take up as much oxygen a pulmonary vascular bed is capable of absorbing Patients with anoxic anoxia due to disease are often improved temporarily by the increased oxygen delivered during anaesthesia, when a high proportion of oxygen not only maintains the haemoglobin satura but allows an increase up to 2 per cent in the blood plasma as a result of the raised r alveolar tension

Anaemic anoxia due to blood loss during the operation is corrected by approp amounts of transfused blood while stagnant anoxia, which accompanies early perip failure because the fully oxygenated blood yields up most of its oxygen before it rea many of the tissues due to its slow rate of flow through the capillaries, requires the procec available for countering surgical shock Perhaps the most valuable of these is to (operating for a short time as soon as the signs of peripheral failure are noted by sur or anaesthetist, so that resuscitative measures may be given a full chance without l negatived by further traumatizing surgery Noradrenaline is of value in raising the b pressure if used at the right stage

Histo-toxic anoxia is best prevented by the adequate pre-operative preparation of t patients Perhaps the biggest risk that must be taken in this repect is when radical sur measures, often the only hope of causing reversal of the process, are being employed fo treatment of chronic lung or pleural sepsis in patients who may even have amyloid dis(

Dangers of oxygen lack

Severe anoxaemia, even for the briefest period, causes damage to the tissues of central nervous system and this may be permanent The occasional tragedy of perma mental deterioration in children who become severely anoxaemic after obstruction to ventilation, the result of bronchial obstruction by muco-purulent sputum during exci operations, can never be forgotten Lesser degrees of post-operative violence, hallucinat exaggerated mental anxiety and depression are probably the result of anoxaemia du the operation or in the immediate post-operative phase Anoxaemia during or a operations may produce serious cardiac damage and possibly the cardiac irregularities s especially after pneumonectomy for cancer in elderly subjects, are due to this

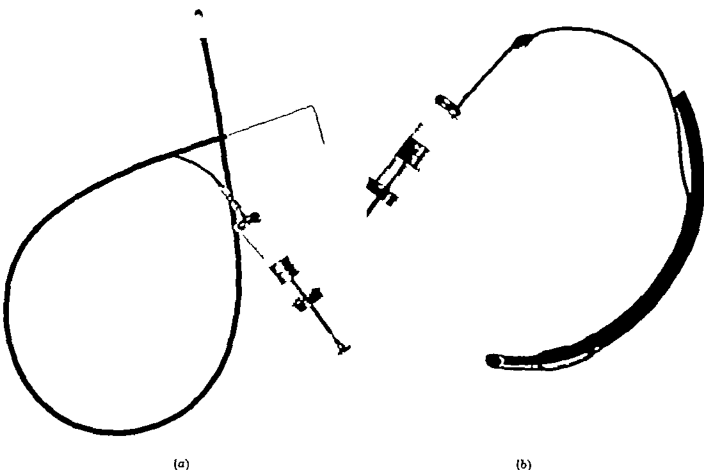
The risks of anoxaemia during operation are best diminished by controlled or assi respiration It is well to remember, however, that the high oxygen tension in the b supplying a respiratory centre already deeply depressed by drugs such as morphine, cu and cyclopropane prevents the stimulus of low oxygen tension, a powerful excitor of centre, from acting and under this mask of depressed respiration carbon dioxide will a mulate unless the absorbing system of soda lime is working efficiently.

Maintenance of an adequate airway

The presence of infected bronchial secretions or of bleeding from the bronchial tr the most serious complication in thoracic anaesthesia , such secretions are liable to from the diseased lung into the trachea or opposite lung with the patient in the clas lateral thoracotomy position or from surgical manipulations of the lung in patients bronchiectasis, carcinoma, or lung abscess To avoid this danger during thoracoplast pulmonary tuberculosis local anaesthesia is popular because the patient retains the co

reflex but local or spinal anaesthesia for major intrathoracic surgery has been tried and abandoned as it fails to prevent lung collapse and mediastinal flapping

Pre-operative postural drainage is the most effective weapon still and on the day of operation must be practised thoroughly Bronchoscopic suction under local anaesthesia before the real induction of anaesthesia is started is a valuable measure in wet patients In the really wet case the area of lung from which the secretions are coming may be blocked off by occluding apparatus of which the best is Thompson s blocker This can be placed in position under local anaesthesia



(a) (b)

Fig 42

(a) Vernon Thompson s bronchus blocker

This is of special value in total pneumonectomy or left lower lobectomy It is introduced through bronchoscope and the terminal cuff is then inflated.

(b) Magill s intratracheal tube with an inflatable cuff

Other procedures for dealing with secretions during the operation are (1) Magill s method of intermittent suction down an intratracheal tube (2) the placing of a tube fitted with an inflatable cuff which is blown up when the tube has been placed in the affected bronchus or (3) the use of one lung anaesthesia In this method a cuffed tube is passed into the bronchus of the sound lung so that the cuff when inflated will lie at the tracheal bifurcation and will shut off the diseased lung This method has the disadvantage of leaving an atelectatic unhealthy lung to which blood from the pulmonary artery still flows without hope of being oxygenated and the carbon dioxide content of the blood may be raised a little Magill s method is to have the balloon inflated when it lies in the sound bronchus thus

allows the diseased lung to collapse and yet prevents its secretions from pouring into the sound side

At the present time Thompson's blocker is the best occluding device (see Fig 4 2*a*), a long pliable rubber tube has a silk-covered inflatable cuff just proximal to its end which is mounted with a perforated metal tip, the large rubber tubing has welded to its wall a thin tube which leads to the rubber cuff, which can be inflated with 3–5 ml of air or water The tube is made stiff by a long malleable stilette passed through the main channel of the catheter. a bronchoscope is passed just above the level to be blocked The Thompson blocker is then introduced through the bronchoscope and when the cuff is in the correct place it is inflated by a syringe attached to a metal fitting at the end of the fine tubing leading to the small rubber bag of the cuff When inflation has been sufficient to cause the cuff to fit snugly in the bronchus the proximal metal attachment is screwed down to prevent the escape of air, the bronchoscope is withdrawn and then the stilette in the blocker tube

If the Thompson blocker is used the lung beyond it can collapse completely which reduces the volume of blood that circulates through it and so diminishes the volume of incompletely oxygen-saturated blood It is ideally used in patients requiring total pneumonectomy for cancer, bronchiectasis or tuberculosis when there is a considerable amount of sputum It is also most useful for blocking the left lower lobe when this is to be resected because of the long length of main left stem bronchus between the orifice of the left upper lobe bronchus and the start of the lower lobe bronchus When the Thompson blocker is in position an intratracheal catheter is introduced through which oxygen and anaesthetic agent is delivered into the normal lung The introduction of the blocker and of the intratracheal tube are awkward manœuvres, best carried out rapidly after complete laryngeal relaxation has been obtained by muscle relaxants of the curare type If the balloon slips upwards during the course of an operation severe interference with the airway to the other lung occurs and this is the most serious handicap to this method of sputum blockage

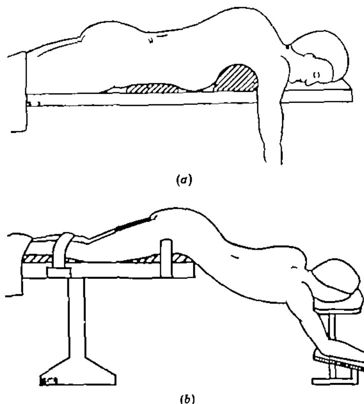
For resection of a wet upper lobe Mrs Mansfield has devised a cuffed rubber tube which can be passed into the bronchus of the side to be operated and so placed that when the cuff is inflated the upper lobe orifice is occluded The tube is so constructed that the anaesthesia passes on into the healthy lung through an opening placed in that part of it which lies in the lower trachea. the portion of the tube that occupies the upper trachea is surrounded by a cuff which when inflated produces an air-tight fit The two tubes may cause trauma and post-operative oedema of the larynx.

The use of postural drainage during thoracic operation

(*a*) *The prone position* (Holmes Sellors and Parry Brown Overholt) This position (Fig 4 3*a*) avoids the spill over of bronchial secretions from the diseased side across the carina into the healthy bronchus and prevents displacement of the mediastinum to the sound side which may happen during operations carried out in the classical lateral thoracotomy position The patient lies flat over carefully arranged pads which lift the upper part of the thorax and the pelvis well off the table and which ensure that the trachea and mouth are always lower than the lungs when the table is slightly tilted in the Trendelenburg position (10–15 degrees of tilt are needed) In this position secretions readily drain down a large intratracheal tube to which is connected a trap for their reception With experience the position is a reasonably comfortable one in which to operate either for lobectomy or pneumonectomy though the incision is not so ample as in the lateral position, but if the patient is arranged in such a way that the side of the thorax to be opened is a little over the

edge of the table or there is a gap between the end of the table and the head piece (Over holt) the incision can be quite extensive (Fig 4 3*b*) The prone position is of great value in operations on subjects with copious sputum

(*b*) *The lateral position with a Trendelenburg tilt* In this position the tilt of the table in the Trendelenburg position for 30–40 degrees allows secretions to trickle down a large intratracheal tube into the face piece and intermittent suction is also used The position is not so effective as the face downward position but has the advantage that it allows the surgeon to use the accustomed lateral thoracotomy incision



(*a*)

(*b*)

Fig 4 3

(*a*) The Sellors-Brown position for right thoracotomy
(*b*) The Overholt type of position.

(*c*) *The upright secretion retention position* At the Children s Hospital Birmingham Dr Margaret Galbraith and I have used this position routinely with satisfactory results in patients with bilateral bronchiectasis (Fig 4 4) In these children copious secretions may block the intratracheal tube in the face down position The aim of the upright position is to prevent purulent sputum from passing into lower lobes or either upper lobe The theoretical objection that an upright position places an undue burden on the heart and lessens blood flow to the brain is not borne out in practice routine blood pressures taken throughout operations of considerable length showing no variation from those in patients dealt with in the more recognized positions The anaesthesia is induced with the patient in a propped up position When the intratracheal tube has been passed suction is applied before turning the patient over on to the sound side during this manœuvre the upper part of the thorax and the head and neck are kept elevated A wooden inclined plane is clamped on to the table and by the use of pillows and sandbags and broad adhesive strapping the child is fixed firmly in a lateral thoracotomy position with the head neck and thorax as upright

as possible The position is a comfortable one for operating and the use of intermittent suction can be reduced to a minimum or even abolished and this allows a smooth anaesthesia to be maintained

Adjustments at the close of the operation

The patient stays in the theatre until the breathing of ordinary air has been re-established This is essential, even if post-operative oxygen is to be administered continuously, so that in addition to oxygen and carbon dioxide tensions in the blood being restored gradually to normal levels the content of inert nitrogen in the respiratory passages can approximate to normal

As the chest wall is closed the lungs should be re-inflated after intermittent suction through the intratracheal tube or after the bronchoscope has removed all possible secretions



FIG 4 4 —The upright secretion retention position (Galbraith and d'Abreu)

The patient is anaesthetized and in position for left lower lobectomy and lingulectomy bronchiectasis is also present in the right lower and middle lobes The object of the position is to prevent gravitation of pus into the upper lobes during the operation

if this is omitted the re-inflation of the lung by the increased pressure in the re-breathing bag may drive plugs of mucus deep into the bronchial tree where they may be inaccessible to bronchoscopic suction If intercostal drainage is being employed the spigot is not placed in the end of the tube until the lungs have been fully re-inflated if drainage is not to be used at the close of the operation, the patient is turned quietly on to the back, a bronchoscope is passed and the bronchial tree on both sides is sucked clear, an artificial pneumothorax apparatus is then used to take off all the remaining intrapleural air An immediate radiograph is of the greatest value in demonstrating the actual intrapleural and pulmonary states

After respiratory equilibrium has been restored an oxygen face piece should be applied and oxygen continued while the patient is wheeled back to the ward on his bed, where he will be placed in an oxygen tent if the indication for oxygen therapy exists

OPERATIVE PROCEDURES

The great range of operative approaches cannot be systematized the pathological processes awaiting surgical correction or assistance often require unique and individually planned surgical approaches The thoracic disease or symptoms may require an operative procedure that is performed in another region altogether e g the use of a collar neck incision for a thoracic goitre causing dyspnoea or dysphagia or the performance of an operation on the phrenic nerve for pulmonary tuberculosis In some operations the neck and the thorax may require approach through one or two incisions or the thorax and abdomen may both require wide simultaneous exposure usually through one large incision But many thoracic operations have standard patterns and it is to these that reference is now made

The approaches may be extra or intrapleural operations they may or may not require a rib resection but as this is commonly so it is proposed first to consider the technical points of a simple rib resection.

Rib resection

The actual exposure of the rib to be resected may be by an incision dividing the overlying skin and muscles made along the line of the rib or across its direction For a large thoracotomy the incision will more usually follow the line of the rib but in the drainage of an empyema or lung abscess it is often wiser to employ a vertical incision so that more than one rib can be exposed which may aid in the actual selection of the rib to be removed During this preliminary stage of skin and muscle division the use of local anaesthesia along the line of the proposed incision is often an aid to haemostasis whether the patient is receiving general or local anaesthesia bleeding points are sealed off by the use of a diathermy point placed in contact with the artery forceps Local anaesthesia injected into the muscles prevents much of the troublesome twitching that accompanies the sealing of vessels by diathermy unless this has been abolished by the curare The rib having been fully exposed, the overlying periosteum is divided along the length of the proposed section halfway between the two borders The periosteum is then firmly scraped upwards and downwards with a sharp preferably curved raspatory (the types described by Tudor Edwards and Price Thomas are excellent (Fig 4 6))

In cleaning this periosteum each movement of the surgeon s hand achieves a definite separation of the membrane and there is no need for ineffectual scratching When the upper and lower borders of the ribs have been clearly defined the curved periosteal elevator will peel the membrane off the upper edge of the rib if the operator works from behind forward and keeps the elevator close to the bone edge The lower edge of the rib is cleared in exactly the opposite direction i e from before backwards It is often easier to clear the lower edge of the rib with a Farabeuf's raspatory than with a curved one If the upper and lower edges are cleaned as described the elevator follows the direction of the external intercostal muscles If the raspatory follows the oblique direction of these muscle fibres the elevation of the periosteum will be clean without the accompaniment of muscle tearing and troublesome bleeding

When the upper and lower ends of the ribs have been cleared meticulously a Doyen raspatory is passed round the rib displacing the few remaining fibres of the periosteum still adherent to the deep surface of the rib the Doyen should be passed at the posterior end of the exposed area of rib Before it is made to encircle the rib the curved elevator is cautiously edged into the posterior part of the parietal envelope care being taken to work

close to the bone The Doyen raspatory is passed from above the rib to emerge at its lower border, this necessitates using a "right-handed Doyen" for a left-sided rib and a left-handed one for a right-sided rib When the Doyen is pushed firmly towards the front end of the rib the actual pressure made by the operator's hand is upwards towards the rib

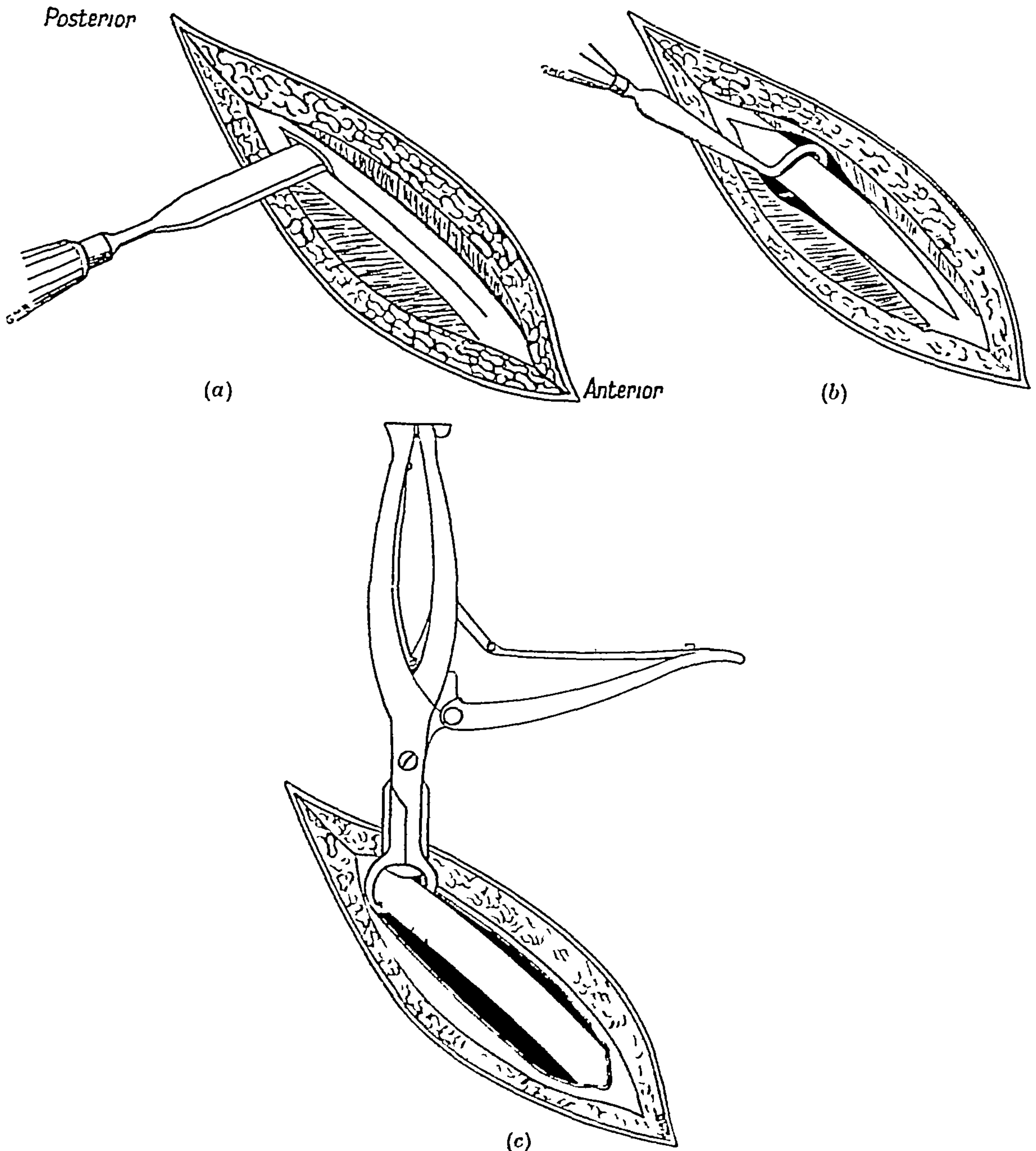


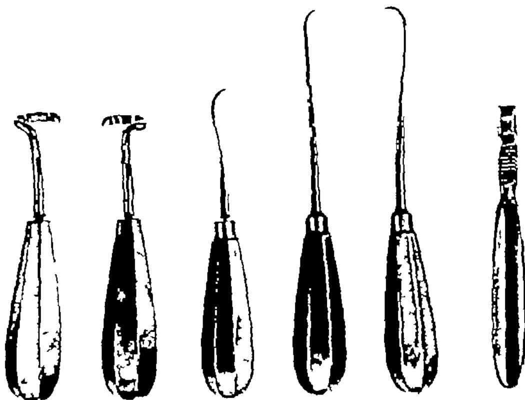
Fig 4 5—Drawing of periosteum being scraped off the rib

(a) The start of the stripping of the periosteum
(b) Doyen's raspatory has encircled the rib and is about to detach the posterior periosteum from the bone
(c) *Tudor Edwards costotome about to make the posterior section of the cleared rib*

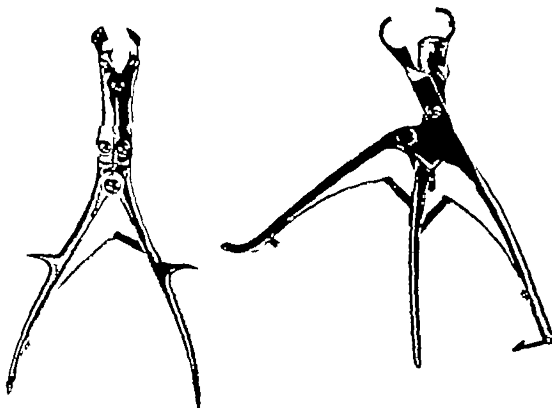
which is lifted off the posterior sheath of the periosteum As the rib is cleared the periosteum falls away carrying in its sheath the intercostal vessels and nerves

Bleeding during these manœuvres is slight It is impracticable to pick up each small vessel that is divided, the bleeding is best checked by the rapidity of each step, because it ceases as soon as the rib has been divided During the actual separation of the periosteum from the bone many small lateral branches of the intercostal vessels are torn

The rib is sectioned by one of the many effective costotomes, the Tudor Edwards' model



(a)



(b)

Fig. 4-6.—Instruments used in rib resection.

(a) Left to right—left and right hand Doyen raspatory; three curved periosteal elevators—Tudor Edwards and Price Thomas; "Farabeuf" raspatory.

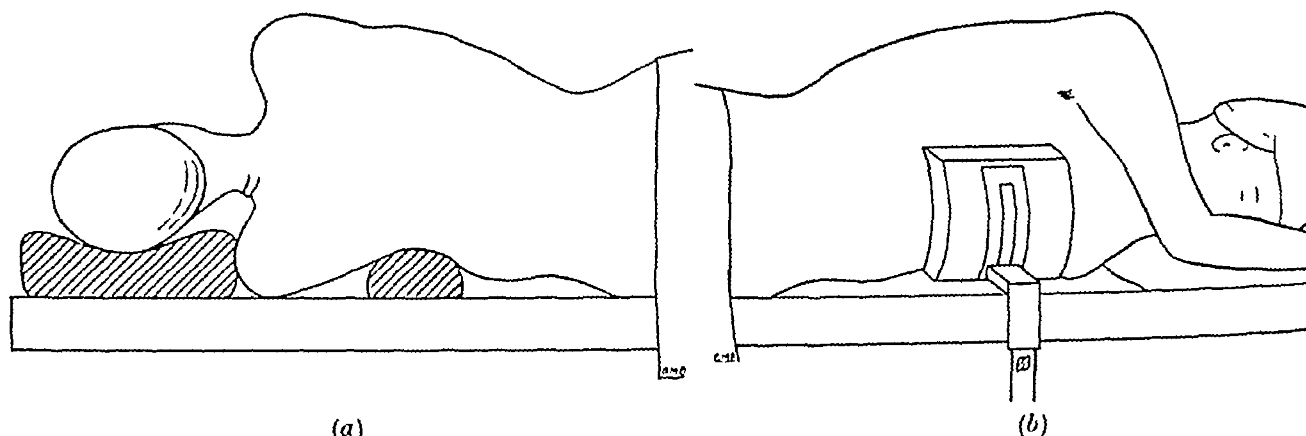
(b) Left: Price Thomas [illegible] rib shears; right: Tudor Edwards costotome.

being popular. In the division of the back end of a rib during thoracoplasty a rib shea preferred, if the bone is to be divided through its neck Alternatively the rib can be near its angle and the distal part disarticulated so that the head and neck are rem entirely if the operation is part of a thoracoplasty

Major Thoracotomy

(1) Posterolateral thoracotomy. When the pleural cavity is opened a wide posure is usually required, the classical exposure is by posterolateral thoracotomy site of this incision depends on the intrathoracic operation to be performed, for the removal of the lung, for an approach to the superior mediastinum, for operation on ductus arteriosus or for cyanotic heart disease (e.g Blalock's operation) the approach be through the bed of the resected fourth or fifth ribs or their intercostal spaces, whe for a lower lobectomy the sixth or seventh will be employed. For the approach to abdomen, operations on the lower end of the oesophagus, the stomach, the spleen, or diaphragmatic hernia, the eighth or ninth rib area will be selected.

Although the thorax can be approached through an intercostal incision with divi of the back end of the ribs above and below the space opened, thoracotomy through bed of a resected rib is simpler, associated with less bleeding and capable of rapid, effic closure because of the periosteum which provides such a good purchase for the sutu



(*a*) (*b*)

Fig 4 7

(*a*) Lateral position as seen from the back
(*b*) Lateral position as seen from the front

It is practised more widely than the approach through an intercostal space except in anter thoracotomy

The incision Whether the posterolateral thoracotomy be high (fourth or fifth r or low (sixth, seventh, or eighth rib) the incision should commence at the outer border the erector spinae muscle, about 3 cm from the vertebral spines and curved forward to nipple line or further, the anterior extension beyond this line will usually only be requi for such incisions as the thoraco-laparotomy one for exposure of the oesophagus, stoma spleen or in a right-sided operation for the performance of a porto-caval anastomosis

The line of the incision should be more oblique in the thin sloping chest of tall t patients in the broad thick chest there are advantages in a more transverse incisi because the ribs run in a more horizontal direction As soon as the skin and subcutanee fat have been freely divided and haemostasis effected, skin towels are applied

Division or reflection of muscles. The latissimus dorsi is a large muscle mass M

surgeons divide this freely and there is no disability from this severe mutilation if careful suture is used in the closure but the surgical objections to such a wide division can be met by reflecting the muscle with only a small division of its posterior fibres If the muscle is divided the auscultatory triangle should be opened and the muscle lifted up between the fingers of the assistant and those of the surgeon. The muscle can then be compressed during its division and the vessels which stand out clearly can be picked up in artery forceps as the incision proceeds The use of the diathermy knife for the muscle incision saves much bleeding The lower part of the trapezius muscle is dealt with in the same way the fibres of this muscle are not encountered in the lower major thoracotomy If the thoracotomy is to be a high one through the bed of the fourth rib the rhomboid muscles will require partial division

If the pleural cavity is to be entered through a high rib space the scapula is held up and the identity of each rib established by counting them from above downwards the second



FIG 4 8.—The Price Thomas rib spreader in place and the ribs slightly retracted
Note that the anaesthetist maintains lung aeration.

rib is readily identified by noting the large digitation of the serratus magnus which arises from it

The rib selected is then resected and the pleural cavity opened by an incision through the posterior wall of the periosteal bed Moist saline swabs are used to protect the edges of the pleural incision before the rib spreader is put in place

The thoraco-laparotomy approach This incision provides a rapid and wide exposure for operations on the upper half of the stomach the lower end of the oesophagus for radical gastrectomy for carcinoma of the stomach and for splenectomy

Operative technique The patient is placed on the table in the lateral position sometimes tilted backwards so that access to the abdomen is made a little easier but this is not necessary A long oblique incision starting from the angle of the eighth rib runs forwards across the costal margin and over the mid abdominal line to reach the outer edge of the right rectus muscle (this extensive thoraco-laparotomy is only required for operations such as total gastrectomy and for less extensive procedures the incision stops at the right border of the left rectus muscle) The incision is deepened to the muscu

muscles are divided by the cutting diathermy point The periosteum of the eighth rib is cleared and the rib with its attached costal cartilage is excised, the incision is then carried across the costal margin and the abdomen is freely opened (if the approach is for a proposed total gastrectomy the abdominal portion of the incision is made first to allow an adequate exploration to be made for the purpose of deciding on operability) The left pleural cavity is then widely opened and the ligamentum latum pulmonis divided to allow the lung to be displaced upwards The diaphragm is divided at right angles to the original line of incision, if the operation is for carcinoma of the lower end of the oesophagus or the upper end of the stomach the diaphragmatic incision proceeds across the oesophageal hiatus fibres As the diaphragm is divided thread or silk sutures are passed through the cut edges on each side to provide complete haemostasis and to act as retractors to the cut muscle. At the oesophageal hiatus large branches of the musculophrenic vessels require to be seized, divided and tied If the operation is splenectomy neither the costal margin nor the oesophageal hiatus requires division

The abdomen and thoracic cavities are now exposed at the bottom of a wide exposure and the organs of both are open to ready inspection Frequently it is quite unnecessary to use retractors but if required the exposure is increased by the use of rib spreaders



(a) (b)

FIG 4 9—Thoraco-laparotomy

(a) The incision along the line of the eighth left rib, which has been excised is carried obliquely across the upper abdomen The diaphragm has been split and temporarily sutured to the edges of the wound by interrupted thread sutures which have been left long Beneath it is a greatly enlarged spleen

(b) The spleen has been easily delivered into the wound preparatory to its removal

(2) Anterior thoracotomy. The approach to the lung, heart and great vessels through this exposure is more cumbersome than the posterolateral one but has certain indications It provides poor access to the hilum of the lung and is not popular for excision operations on the lung whether these be pneumonectomy, lobectomy or segmental removals It is used by many leading American exponents for the operative correction of congenital cyanotic heart disease by Blalock's subclavio-pulmonary anastomosis, for the ligation of the patent ductus arteriosus and for direct cardiac operations such as pulmonary valvulotomy

or mitral valvulotomy In Great Britain the approach is confined chiefly to the operation of pulmonary valvulotomy (Brock) or for pericardiolysis

The incision Unless a curved incision through the inframammary line is used the scar is unsightly especially after transverse incision made above the nipple The incision favoured by Brock provides an excellent exposure and a good cosmetic result The third interspace is widely exposed through a curved incision that runs along the inframammary fold but does not curl up too high in the axilla The breast and pectoral muscles are detached completely below and swung upwards with the skin as one large flap which is then encased in moist saline pads The dissection is carried well backward so that the posterior parts of the third and fourth ribs are thoroughly exposed this step should be carried out thoroughly The third interspace is then opened freely the perichondrium of the third and fourth costal cartilages is elevated and then both are divided obliquely with due care taken over the exposure of the internal mammary vessels which are ligated and divided



Fig 4 10—Anterior thoracotomy incision

The wound is closed by careful suture of the intercostal space after the divided cartilages have been brought into apposition with their sternal ends by silver wire sutures The detached pectoralis and breast are re-sutured in position and the skin closed

(3) **Axillary thoracotomy** A small as yet unestablished place exists for this operation namely infrastellate ganglionectomy in the treatment of some neuro-vascular disturbances of the upper limb (Atkins 1949) The pleural cavity is exposed by an axillary incision and the third intercostal space opened without rib division The lung is held away by suitable retraction after the space has been spread and the sympathetic cord is divided below the stellate ganglion and the posterior roots of 2 3 and 4 thoracic nerves divided.

(4) **Trans-sternal thoracotomy** This approach is almost exclusively reserved for operation on thoracic goitre removal of the thymus and for pericardial resections in the relief of constrictive pericarditis Most thoracic goitres can be removed safely through a cervical incision but the sternum may require division quite exceptionally (see p 476) A trans-sternal approach may be required in the course of the search for parathyroid tissue in patients with osteitis fibrosa cystica

The incision This commences with a small transverse cervical incision about ½ cm above the supra sternal notch From the centre of this the main stem of the T shaped incision divides the skin and subcutaneous fat in the mid sternal line Normally this may extend to the level of the third or fourth costal cartilage but occasionally the bone requires exposure and division as far as the ensiform cartilage Conversely a lower median sternotomy for the exposure of a constrictive pericarditis operation may start at the xiphisternum and proceed upwards as far as the second costal cartilage level where the bone is transected before being spread apart The length of sternal split will depend entirely on the

a few pathological states are encountered which provide problems of a specific nature These are congenital deficiencies or deformities and tumours of the ribs and sternum Tuberculous conditions of the chest wall are considered on page 257

Congenital deficiencies

These are rare The absence of a large part of the sternum is associated in extreme examples with ectopia cordis and no successful treatment of this has been recorded Absence of ribs is commoner and is usually associated with a hernial protrusion of the lung or of abdominal viscera (Fig 4 11) In the instance illustrated the deficiency of the left lower ribs is associated with an upper abdominal hernia at the age of one this was satisfactorily corrected by the use of large grafts obtained from the fascia lata In the correction of congenital lung hernia use may be made of adjacent ribs which are sectioned or partially split and swung into new positions and fixed to their neighbours

Funnel chest (pectus excavatum)

In this congenital condition the lower part of the sternum is depressed inwards and the depression rarely involves the manubrium The cartilages attached to the sternum are longer than usual and are acutely angulated at their junction with the ribs proper and with their sternal attachment In severe degrees of the deformity the lower end of the sternum is in contact with the vertebral column the heart being displaced completely into the left side of the chest and altered in shape

An opportunity to study the shape of the heart was provided by a woman of 48 with a severe degree of pectus excavatum. She came to hospital with a carcinoma of the middle third of the oesophagus which was treated by excision followed by oesophago gastrostomy (Fig 4 12) After the oesophagus had been exposed by a thoraco laparotomy the posterior surface of the sternum was seen to be less than a centimetre from the vertebral column into this small space was crushed a portion of the right auricle and right ventricle and the heart was peculiarly discoid in shape during the manipulation necessary for the elevation of the oesophagus the heart became violently irregular from pressure against the bony framework In spite of the severe degree of the deformity this patient had no cardio vascular symptoms and recovered well from the operation.

The etiology of the condition remains obscure it may be familial. The assumption that the whole deformity is started by the contractions of a shortened diaphragmatic attachment to the lower end of the sternum associated with a tense short substernal ligament is hard to believe Sweet (1950) favours the view that the sternum is depressed by the powerful posterior thrust of the deeply incurved costal cartilages Whatever the etiology it is clear that division of the substernal ligament and of the diaphragmatic attachments does little to improve the deformity

The indications for surgical correction are for cosmetic reasons or in the unusual event of cardio respiratory symptoms dyspnoea and cyanosis may develop from mechanical distortion of the heart and a decrease in lung ventilation The operation is a severe one and should not be employed lightly

The operation The description given is based on Sweet s modification of Lincoln Brown s (1940) operation Three main points require attention the excision of portions of costal cartilage to remove the downward thrust of these and to correct their abnormal articulation with the sternum the elevation of the depressed portion of the sternum by means of a wedge osteotomy just below the junction of the gladiolus with the manubrium

and the re-attachment of the divided cartilages to the side of the sternum after small transverse osteotomies have been performed on the ribs to correct their inward curving

The operation is carried out under general intratracheal anaesthesia, as the pleural cavities may be opened accidentally. The sternum is widely exposed through a long midline incision which extends from the manubrium well on to the abdomen; the pectoralis major muscle on each side is divided from its sternal and costal cartilage origins; below, the linea alba is incised and the rectus abdominus muscle cleared from the lower costal cartilages; the ziphisternum is grasped in tissue forceps and the anterior mediastinum entered beneath and a space created between the sternum and the pericardium. A small wedge-shaped portion of the sternum is removed from the anterior cortex of the bone just below the site where the posterior depression starts and the depressed portion of the sternum

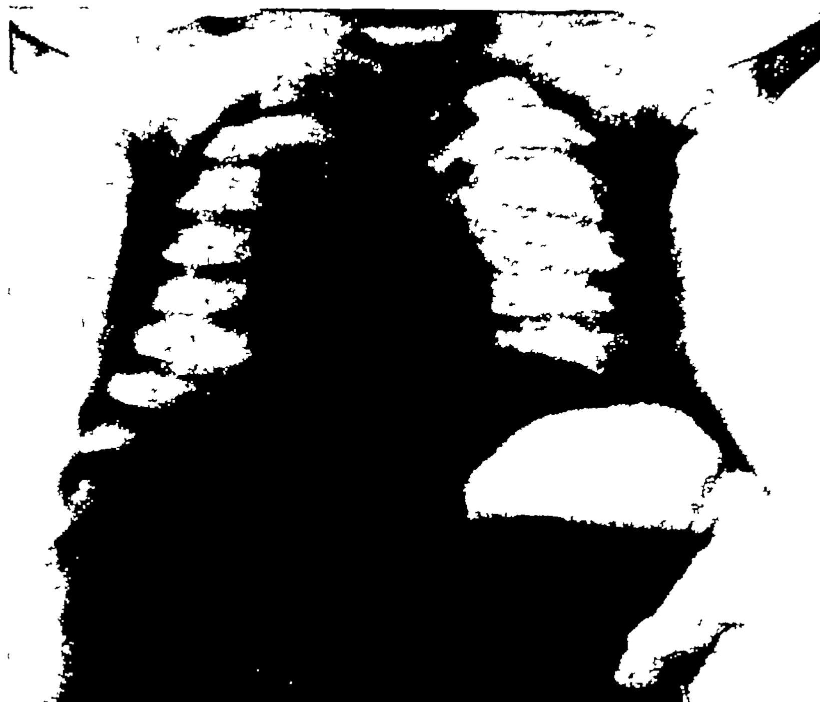




FIG 4 11 FIG 4 12

FIG 4 11 —Congenital hernia through a deficient left chest wall

FIG 4 12 —Pectus excavatum

The patient, a woman of 48, three weeks after oesophagectomy for carcinoma of the mid thoracic oesophagus. At operation the posterior portion of the sternum was less than one centimetre from the vertebral column, and the heart was severely distorted and compressed; there were no cardio-respiratory symptoms

can then be levered upwards. The distorted articulations of the costal cartilages with the sternum are then excised and the cartilage or rib angulations are corrected by small wedge resections carried out at the site of maximum angulation. Sufficient costal cartilage is resected to allow an accurate apposition of the remaining stumps to the side of the sternal body in their new correct line

The sternum is fixed at the site of the osteotomy by several stainless steel sutures and the cartilages fixed firmly and by a good fit to the side of the sternum by stout silk or wire sutures. In a similar way the osteotomy sites on the ribs are steadied by suture. The ziphisternum is removed; the pectoralis major on each side is sutured to the periosteum of the sternum

It is doubtful if traction on the sternum is necessary. If, however, there is any hint of instability a stainless steel wire is passed through the central portion of the gladiolus

and the ends are brought out through the skin for subsequent incorporation for 10–14 days in a heavy wire loop supported by a moulded plaster fixed to the chest so that steady traction is maintained

Tumours of the ribs

These may be innocent or malignant primary or secondary metastatic tumours are the commonest group encountered Chondroma or chondro-sarcoma of the chest wall are probably the next commonest primary tumours Fibroma or fibro-sarcoma may be isolated or part of the general disease of multiple neuro-fibromatosis (von Recklinghausen s disease) Ewing s sarcoma and giant-celled tumour (single myeloma) are rare In multiple myelomatosis the ribs are almost invariably involved. Cystic changes may be present in the generalized bone disease of osteitis fibrosa cystica associated with a parathyroid tumour or hyperplasia or renal disease

Excision of ribs for primary tumours

As the commonest primary tumour is a chondroma or chondro sarcoma which tends to local recurrence a wide excision is essential The rib should be excised through a thoracotomy incision from its head to its costal cartilage the adjacent pleura periosteum and overlying soft tissues being removed widely with no attempt being made to enucleate the tumour from surrounding tissues If the tumour is adjacent to the sternum a portion of that bone should be excised to leave a wide margin from the tumour

When malignant invasion has taken place an operation of considerable magnitude may be necessary involving the removal of a wide area of the chest wall and possibly of infiltrated lung tissue After wide excision of the chest wall stability may be encouraged by the use of tantalum gauze and other reconstructive measures

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CHAPTER 5

POST-OPERATIVE CARE OF THE THORACIC PATIENT

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General hygiene and nutrition, combined with measures to maintain correct fluid and electrolyte balance, satisfactory haemoglobin levels and adequate lung ventilation in the pre- and post-operative phases, prevent or modify post-operative complications, not only in the thoracic surgical patient, but amongst those in all branches of surgery

Principles

After operation a rapid return to normal respiratory physiology requires that in all the remaining lung parenchyma the gaseous and fluid interchange between the pulmonary blood and the atmosphere takes place in the presence of a satisfactory cardio-vascular system transporting cells and plasma well stocked with biological essentials The functional lung units must be aerated, ventilated and perfused by pulmonary blood in the presence of an alveolar membrane capable of normal diffusion

The essentials are

(1) The maintenance of an adequate breathing mixture air at normal temperature usually suffices but may have to be augmented in certain types of pulmonary failure

(2) A clear airway from the exterior to the alveoli and re-establishment of full lung volume with the pleural space occupied only by the normal partial vacuum with the parietal and visceral membranes in contact This ideal may not always be attained at once after some resection operations.

(3) Encouragement of normal breathing with a chest wall and diaphragm as actively mobile as possible

Pre-operative physiotherapy, with its respiratory education and improvement in muscle elasticity and tonus, greatly eases the burden of the early post-operative days The position of the patient in bed is important In general, the supine position allows bilateral respiratory movement in three planes, enabling the diaphragm to move upwards and downwards, and the ribs to come forwards and laterally with only the posterior movements of the chest wall hampered The normal chest or sitting position embarrasses diaphragmatic movement so that the lung bases are poorly ventilated The patient's field of vision in the supine position can be increased by elevating the head of the bed

The generalization that the supine position is the most acceptable one requires qualification Where pulmonary blood flow is embarrassed, as in early left-sided failure or in pulmonary hypertension, dyspnoea in the recumbent position is often relieved when the lung congestion is decreased by the assumption of the sitting-up position, cyanosis after pneumonectomy for the same reason is often corrected by using the orthopnoeic position which decreases the minute volume blood flow to the remaining lung and lowers the cardiac

output * the cardiac output however is not greatly altered if the degree of heart failure present is considerable

Generally speaking the supine position is preferred for the first 24–48 hours post operatively Modifications are required after certain operations and will be discussed later

Easy breathing is helped by suitable analgesic sedatives and narcotics which also reduce mental anxiety and over action of the stress adaptation mechanism

Maintenance of cough reflex

The restoration of normal respiratory physiology after major thoracic operations depends largely on the early and sustained return of this reflex which establishes a clear airway and encourages aeration of the lung parenchyma with normal intra alveolar tensions

Churchill (1949) emphasizes that the two main functions of cough are the expulsion of mucus from the upper tracheo bronchial passages and the forcing of air into the alveoli

The bronchial musculature spreads along the bronchioles to the atria encircling the mouths of the alveoli to form definite sphincters which trap air on expiration and only allow it to leak away gradually this mechanism maintains a relatively permanent high intra alveolar tension Cough therefore efficiently clears the upper respiratory tract maintains alveolar tension and possibly by providing a correct pressure against the capillaries of the lung parenchyma lessens the tendency to oedema development

Coughing however is not without its ill-effects The ineffective cough especially when small and repeated in established atelectasis with bronchial occlusion and peripheral air absorption may serve to push exudates and infected material further into the lung parenchyma it may disseminate tubercle bacilli from one area of the lung to others and in broncho-pleural fistulae leading from an empyema may produce septic aspiration effects in the other side The small half-expressed cough encountered during the performance of a lipiodol bronchography does not expel the oil entirely but often drives it into the bronchioles and alveoli

Pulmonary atelectasis

This is probably the most important complication that arises and plays the chief part in the pathological cycle that follows its onset

Sir William Tennant Gairdner (1850) described atelectasis and quoted Gregg (1832) as being the first to differentiate between areas of atelectasis and true lobular pneumonia Many causes for its development were suggested Pasteur (1914) suggested spontaneous loss of air content as an explanation

Classifications The anatomical distribution may be lobular or patchy segmental lobar or massive (i e two or more lobes) The mechanical causes may be intrinsic such as inspissated mucus in the air passages foreign bodies or kinking of a bronchus or extrinsic from the pressure of air or fluids in the pleural space on the lung or resulting from immobility collapse or paralysis of the overlying chest wall or diaphragm

The natural history of atelectasis is that early collapse is capable of spontaneous recovery the intermediate variety associated with infection or pneumonitis is probably recoverable if the bronchial tube regains its patency but the late irrecoverable type may lead to lung abscess or bronchiectasis

* Cardiac output is increased by 30 per cent on changing from the upright to the recumbent position under certain experimental conditions (McMichael and Sharpey-Schafer 1944) It is not at all certain that the postural changes made in these well known studies are in fact reproduced by the movements of a patient whose position is altered in bed from the sitting to the lying state

Etiology Acquired collapse can be briefly classified as

(*a*) Compressive or passive
(*b*) Obstructive or active

The relation of pressure from without to collapse ("passive" collapse) is easily understood and follows naturally upon pneumothorax, pleural effusions, distortions of the thoracic cage and pressure from tumours "Active" collapse follows directly upon bronchial obstruction as we now understand it, but for many years various theories were propounded in explanation

Pasteur (1914) suggested a "reduction in depth of respiration" as the cause chiefly on the basis of atelectasis developing in post-diphtheritic paralysis patients, Bradford (1917) blamed spasm of the chest wall as the cause, Gwyn (1923) and Churchill (1925) were interested in vasomotor broncho-motor disturbances

The two main theories of bronchial obstruction and of reflex nervous mechanism were unified in a masterly contribution by Coryllos (1930), who believed bronchial obstruction to be the determining cause of the disease

Lindskog and van Allen (1931) showed that this is not quite the entire story as lobular bronchial obstruction can be compensated for by collateral respiration or aeration from other unobstructed lobules This is usually impossible at the lobar levels Obstructive collapse may follow lobar or lobular bronchial obstruction if combined with obstruction of the interatrial and interalveolar communication to other lobules This latter fact can happen as suggested by Churchill either by mucous debris which is aspirated, or by that which is produced locally, peripheral to the obstruction, by the mucous secreting cells of the bronchioles Alternatively physiological shut-down of these communications may occur during shallow respiration and account for lobular collapse

Atelectasis may develop rapidly as the result of straining expiration against an obstruction, with valvular mechanism in the air passage that permits the exit but not the entrance of air (van Allen and Adams, 1930), or the presence in the alveoli of the easily absorbable carbon dioxide and pure oxygen without the space-occupying effect of nitrogen This happens when cyclopropane has been used as an anaesthetic, unless great care is taken towards the close of the operation to re-fill the air passages with normal air

Incidence Atelectasis develops in 2 per cent of all general surgical cases with half per cent mortality In thoracic surgery the highest incidence is seen after lobectomy for suppurative bronchiectasis, being at the rate of 26 per cent in 106 resections as compared with no instance in 16 lobectomies done for non-suppurative bronchiectasis (Gray, 1946) The post-operative state of the bronchi and bronchioles clearly plays an important rôle in the pathogenesis of the disease, and this justifies the use of pre-operative measures designed to counteract infection and bronchial debris It is commonest in suppurative pulmonary conditions, particularly in the "wet" cases of bronchiectasis (especially when bilateral) and in pulmonary tuberculosis

Symptoms and signs. Symptoms usually arise in the first 48 post-operative hours but may be delayed for a week or rarely ten days There may be obvious distress with dyspnoea, cyanosis and pyrexia, but in most patients the onset is insidious and undramatic with the nursing staff reporting a state of malaise with reluctance to eat or drink

Characteristically respirations rise to 30–60 per minute and are laboured and ineffective Pyrexia of 100–102° is usual and a frequent but ineffective cough adds to the picture of general distress A little tenacious viscid sputum may be expectorated Cyanosis is present but is not marked

The chest wall movements are poor especially over the area of the underlying collapsed lung because of the high intrapleural negative pressure the mediastinum is displaced to the side of atelectasis the intercostal spaces are narrowed and the chest wall may move paradoxically The mediastinal shift may not be marked in the immediate post-operation phase and a normally placed trachea and apex beat may accompany atelectasis Breath sounds may be poor with adventitious moist râles or absent or characteristically bronchial in type

The stethoscope may provide useful information as to the degree to which atelectasis has progressed In the early phase of bronchial occlusion poor or absent breath sounds are the rule and vigorous treatment may lead to rapid recovery Bronchial breathing indicates consolidation the regained bronchial patency being accompanied by oedema or frank pneumonitis in the periphery of the lobe or segment

Radiological appearances The X ray changes usually make the diagnosis certain if both anteroposterior and lateral views are taken Typically the lobe is opaque but areas of aeration may be due to air drift The mediastinum is drawn over to the collapsed side and the ribs are approximated with the diaphragm in a raised position

Treatment of atelectasis

Prophylactic The pre-operative measures of physiotherapy the active co-operation of the patient in learning good respiratory movements and the improvement in muscle tone are of great value The control of infection and the restoration of fluid and haemoglobin levels are achieved as far as possible Certain patients are especially prone to post operative collapse these are the nervous apprehensive individuals particularly the thyrotoxic and the young below the age of 10 Upper respiratory sepsis suppurative lung conditions such as bronchiectasis lung abscess and pulmonary tuberculosis associated with heavy sputum production are naturally liable to cause this complication. Therefore dental and rhinological attention postural drainage and antibiotics should be utilized to improve these conditions pre-operatively

A reasonable time interval should be allowed between a bronchographic examination and operation Belsey (1937) recommends at least a period of 8 weeks This delay is advised especially when radiographs indicate the retention of much oil in the bronchioles and alveoli.

For a short period surgeons hoped to prevent collapse of the remaining lobe after excision of lung tissue by producing an artificial symphysis of the visceral and parietal pleurae (chemical pleurodesis) This is no longer attempted because atelectasis depends far more on the effects of bronchial obstruction than on passive collapse of the lung The chemical irritation of the pleura was distressing to the patient and was rarely effective if truly effective its very presence impairs the compensatory over-expansion of the remaining lobe which is required to fill the hemithorax (Chesterman 1943)

Prophylactic measures during operations The care of the patient during the induction of anaesthesia has been described elsewhere (p 65) pre-operative bronchoscopic aspiration blocker devices special positions on the table and the use of suction through a large intratracheal tube are everyday procedures Sedation should be light and the anaesthetic itself should be accompanied throughout by adequate oxygenation of well ventilated lungs The cough reflex should recover rapidly at the close of the operation The patient should not leave the operating theatre until this reflex is fully re-established In the hope of preventing post-operative pain many measures, such as section of the intercostal nerves

their anaesthetization by the local injection of procaine in oil or water solutions, have been advocated An extensive trial of these measures has been disappointing

Post-operative measures. These begin in the theatre. The bronchial tree should be sucked free of pus, mucus and fluid by catheter or bronchoscopic aspiration and the intrapleural pressures adjusted to normal If the operation has been concluded by providing closed intercostal drainage the anaesthetist will have fully re-inflated the lobe or lung, if the chest has been closed without drainage the intrapleural pressures should be checked by means of an artificial pneumothorax apparatus with the patient supine A radiograph should then be taken

In general the supine position of the patient in bed is adopted unless special reasons exist Immediately after lower lobectomy the sitting position is contra-indicated as the unsupported upper lobe, by falling down under the influence of gravity, may kink its bronchus and prevent full re-aeration The foot of the bed may even be raised slightly until the lobe has expanded to fill the pleural cavity

The constant change of position obtained by rolling the patient from one side to the other at hourly intervals is valuable when an ineffectual cough with the expectoration of viscid sputum arouses the suspicion that atelectasis is developing. After lobectomy, lying on the unoperated side may assist the re-expansion of the residual lobe, while respiratory distress after pneumonectomy is often decreased if lateral decubitus is adopted with the operated side undermost

Although both morphine and the barbiturates may minimize the effect of stimuli to the respiratory centre, the use of morphia in doses of gr $\frac{1}{8}$–$\frac{1}{4}$ [8–16 mgm] at four-hourly intervals is justified Analgesia sufficient to relieve pain in the wound that otherwise would cripple the coughing mechanisms and prevent the removal of bronchial secretions is the usual practice Care should be exercised in giving repetitive doses of morphia to elderly subjects

Unfortunately many patients, particularly after thoracoplasty, are sensitive to the emetic factor in morphia and in such physeptone or pethedine can be substituted

The periodic use of 5 per cent CO_2 in O_2 mixture to maintain maximum ventilation as a preventive measure against atelectasis is rarely indicated except in special cases when breathing is shallow and under-ventilation is obvious When bronchial occlusion is established its use is unwise because forced breathing may drive infected material deep into the bronchioles which may cause pneumonitis Helium combined with oxygen, being an extremely light gas, allows easy ventilation of poorly aerated areas

The value of good physiotherapy can hardly be overstated in helping to clear partially obstructed bronchi

Expectorants are of doubtful value Ammonium carbonate in 10 gr doses hourly for six doses may help patients who are attempting to cough up viscid sputum, it is difficult to proscribe the use of the various linctus mixtures which have a soothing taste and a psychological value far beyond their pharmacological efficiency

Antiseptics and antibiotics such as penicillin in the dosage of 30,000 units three-hourly or given in two large doses daily of slowly diffusing solutions are used routinely, aureomycin is of greater theoretical value as it affects a wider range of organisms

The routine use of antibiotics may well be unnecessary but few surgeons dare to forgo their administration until specific indications of infection appear nevertheless time will probably see the adoption of curative rather than prophylactic antibiotic therapy

Atropine is inadvisable as its effect on the bronchial mucosa is to make secretions more tenacious, thereby embarrassing the work of the cilia Its systemic effect on the patient

is disagreeable because the tachycardia and the drying effect on the mouth are combined with an excitant action on the mental processes

The maintenance of a correct fluid and electrolyte balance also helps to keep bronchial secretions thin.

Treatment of established atelectasis

Atelectasis falls into two distinct phases (a) the early stage of bronchial obstruction and (b) the later stage of consolidation

(a) *The early stage* The raised intrapleural negative pressure impaired percussion the altered breath sounds and the other physical signs indicate the underlying pathology of bronchial obstruction with absorption of the air distant to the plug and atelectasis of the lobe or lobule

The re-establishment of bronchial patency at the earliest possible moment is clearly indicated After a short but thorough attempt to unblock the bronchus by physiotherapeutic measures such as rolling and postural drainage bronchoscopy should not be delayed if success has not been achieved.

Bronchoscopic aspiration is an easy and efficient method which can be done in the ward under local anaesthesia General anaesthesia would obviously delay coughing which occurring during the procedure expels mucus and pus from the smaller bronchi and brings it within reach of the aspirating tube passed down the bronchoscope Suction must be deliberate and thorough At the end of the procedure normal ventilation of the involved area should be obvious with the immediate return of breath sounds

Physiotherapeutic methods must follow and further bronchoscopies are done if the lobe collapses again

Alternatively the good method of Haight (1938) of overcoming bronchial occlusion by trans tracheal catheter suction through the nose may be used Bronchoscopy however appears to be as easy more efficacious and no less trying to the patient in the hands of those used to its routine both in diagnosis and treatment

(b) *The later stage* This stage may be looked upon fundamentally as one of recovery where the bronchi have again become patent but the alveoli remain airless owing to an accumulation of debris rapid progress to full recovery now depends on the presence or absence of pathogenic bacteria Diagnosis is made on the presence of bronchial breathing along with the more usual signs of collapse When this stage is reached bronchoscopy is of doubtful value reliance being placed on antibiotic and antiseptic methods against the threatening bacterial invasion

Surgical emphysema

A mild degree of surgical emphysema in the region of the wound is common and of no significance as the air is rapidly absorbed it is the result of post-operative coughing forcing any remaining intrapleural air through the wound layers If lung tissue has been incised as in lobectomy or segmental resection air may continue to bubble out into the pleura and through the pleural incision. If the chest has not been drained or the intercostal tube has been removed the appearances may be alarming

Air may be driven into the lower abdomen or up into the neck and face If the intra thoracic state is satisfactory even the worst degrees of surgical emphysema will be absorbed without any specific treatment A radiograph of the chest is essential to ensure that the remaining lobe has re-expanded. If a tension pneumothorax is diagnosed by symptoms of increasing dyspnoea accompanied by tachycardia and engorgement of the neck veins

with the radiographic appearances of mediastinal displacement, an intercostal needle or tube leading to an underwater sealed drainage system should be instituted at once (see Fig 23 4)



Fig 5 1 —Gross surgical emphysema after a segmental resection for bronchiectasis In spite of the alarming appearances the lung was fully expanded and no specific treatment was given the condition subsided completely in four days

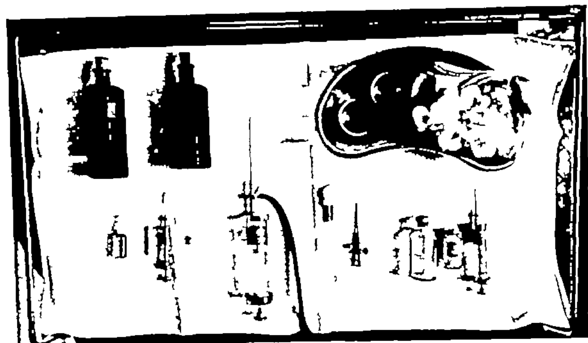
Post-operative pleural effusions

The commonest complication of thoracotomy is a sero-sanguinous effusion These post-operative collections depend in the main on the operative trauma which involves damage to serosal surfaces and blood vessels and lymphatic channels

Post-operatively, a high negative intrapleural pressure, especially if continuous when associated with collapse of the lung, leads to an outpouring of fluid The water and electrolyte balance of the patient may be important contributory factors Chloride retention, renal and cardiac failure and certain anoxic states consequent on surgical shock may encourage pleural effusions Hypoproteinaemia is also a recognized cause and may be aggravated when associated with vitamin B and C deficiency Infection of the pleura may be followed by the classical signs of inflammation with the outpouring of inflammatory exudate Blood itself in the pleural cavity excites effusions and this underlines the importance of good aspiration technique, when reliance is being placed upon aspiration in the management of such collections

Nature of effusions In view of the underlying etiology it is clear that effusions may be serous, sero-sanguinous, purulent or chylous Especially important is the fact that haemothorax fluid may clot and the organization of such a process may constrict the lung and limit the chest wall movements When such organization begins to take place the *effusions may become loculated forming a series of complicated pockets* which in turn may become infected (see Chapter 23)

Sero-sanguinous effusions may clot in the absence of infection , that blood will clot



(a)

(b)

FIG 5-2 —Trolley and set for post-operative aspiration of pleural effusion using Stott's artificial pneumothorax apparatus.

(a) Below the antiseptic solutions and the wool swabs, etc., are placed an ampoule of local anaesthetic, the file for opening it, a hypodermic syringe and needle for its injection; to the right of this is a 10 c.c. record syringe with two-way tap attachment, exploring needle and rubber tubing attached, sterile test tube for the bacteriological and cytological examination of aspirated fluid, an artificial pneumothorax needle, sterile water and bottle of crystalline antibiotic together with syringe and needle for its intrapleural injection.

(b) When the exploring needle with its two-way tap has reached the intrapleural effusion, the removal of the latter is facilitated by the use of the artificial pneumothorax apparatus shown connected to a Winchester for the collection of fluid and air aspirated.

in the early stages is obvious to any surgeon who has opened the pleura, but usually post-operative clotting rapidly becomes defibrinated, probably under the influence of the cardiac and thoracic movements In the absence of infection the clots are usually fragile and quite different from the chocolaty-brown ones noted in the infected haemothorax (see p 527).

The principle established in the war that a haemothorax should be aspirated in the very early stages should be applied with emphasis to post-thoracotomy effusions.

Morbidity Most post-operative effusions are of minor importance but serious troubles can arise depending on the size, nature and possible infection When these effects are compounded the patient may show the effects of toxaemia, wound shock with its circulatory effects, hypoproteinaemia, pulmonary oedema and the embarrassment of respiration due to passive pulmonary collapse The more serious later effects depend on the pathological process of organization into fibrinous haemothorax or, following infection, the onset of a frank empyema Cardiac arrythmias may be due to the effects of such pressure and are accentuated after intrapericardial procedures

Post-operative treatment The early diagnosis of these effusions by clinical and radiological signs should lead to their immediate and complete aspiration War-time experience has shown that after frank haemorrhage aspiration need only be delayed for 12 to 24 hours. Aspiration encourages full and rapid expansion of the lung or lobe with obliteration of the space, so that clotting, loculation and infection are prevented Small effusions, however, often resolve satisfactorily without treatment

Aspiration technique Pre-medication by omnopon and scopolamine is used The patient should be propped up in a comfortable position with pillows suitably placed, frequently aspiration after transpleural operation can be carried out most satisfactorily in the axillary line Local anaesthetization of the skin and pleura of the selected intercostal space allows a large-bore needle to be used without discomfort to the patient The use of a two-way syringe has been found to be most satisfactory The Potain's aspirator is not in general use today Following aspiration antibiotic drugs such as penicillin or streptomycin are instilled into the space if indicated

Loculated effusions require multiple aspirations but when infected or clotted the usual principles governing the management of empyema and multiloculated effusions (see p 116) are adopted with recourse to surgical clearance These measures include rib resection and drainage or thoracotomy, clot clearance and pulmonary decortication

Chylo-thorax. This complication deserves special mention It may be due to malignant disease not necessarily primarily focused in the lung in which the lymphatics become blocked, or it may be associated with trauma, cases being seen in which a chylous pleural effusion follows injury, not necessarily of severe magnitude The commonest type seen in thoracic surgery is probably after the performance of a Semb's extrafascial apicolysis This may be associated with oozing from the wound of typical chyle or rapid development of a massive effusion If untreated, the patient loses weight, shows a low white cell count, particularly lymphopenia and eosinophilopenia, and the correct measure is to identify and ligature the damaged duct as soon as possible The complication is occasionally seen after intrathoracic operations involving dissection usually on the right side of the posterior mediastinum, as in the operation of thoracic sympathectomy for hypertension Strangely enough its occurrence after oesophagectomy is most unusual

Post-operative broncho-pleural fistula

Broncho-pleural fistulae still provide a problem after lung resection and their detection and management remain difficult Better surgical technique and the antibiotic agents have

greatly decreased their incidence but disease processes such as malignant tissue invasion or tuberculous tissue of the bronchial stump are responsible for some Since the individual ligation technique in lung resection was adopted there has been a notable decline in fistulous complications In a recent series of 230 resections at the Queen Elizabeth Hospital (1948 1949) (d Abreu and Brain) performed by the individual ligation method and with the use of antibiotics the fistula incidence has been as follows

	No of cases	No of fistulae	Percentage
Pneumonectomy for carcinoma	94	0	10
Resections for bronchiectasis	95	3	3 5
Resections for pulmonary tuberculosis	50	5	10

When children only are considered the incidence is minimal At the Children s Hospital Birmingham in a consecutive series of 80 resections which included 10 pneumonectomies and 70 lobectomies or segmental resections there has been one fistula this being the only patient in the series who developed an empyema (d Abreu)

Types of bronchial fistulae The fistula may be *early* developing within the first two post-operative weeks and serving as a reminder that the techniques for bronchial closure are still not perfected Or *late* when it is heralded months or even years after resection and associated with an undramatic dormant empyema or representing a malignant necrosis after pneumonectomy for carcinoma of the lung In this latter group the development of an empyema may be insidious and overlooked the emaciation and falling away of the patient being attributed to a malignant recurrence until the sudden expectoration of pus discloses the presence of the empyema. Such a fistula developing suddenly may cause death immediately or later because the flooding of the sound side may initiate a fatal suppurative bronchopneumonia Such possibilities underline the need for the constant clinical and radiological review of the post pneumonectomy space if this has not been obliterated by a post-resection thoracoplasty

Since the early fistula is largely due to technical errors such as inadequate closure avascular necrosis or septic necrosis of the bronchial stump the technical points outlined in Chapter 12 are important

Diagnosis of post-operative broncho-pleural fistula Fistula may follow pneumonectomy or lobectomy with acute dramatic symptoms after a bout of paroxysmal coughing the patient may expectorate a considerable quantity of haemothorax fluid If the opening is small and valvular the symptoms of tension pneumothorax may be added to the picture cyanosis distress tachycardia and distended neck veins being obvious The trachea and mediastinum may be displaced The other lung may be flooded with immediate or later death from the effects of the aspiration

More usually the onset is less dramatic persistent cough with the expectoration of small quantities of blood-stained fluid especially after changes in position indicating that a small fistula has developed

If the fistula develops after the patient has left the hospital two different stories are possible In one the patient returns because of constant irritating cough during which a little blood stained material may be coughed up possibly containing a suture The second and more important group concerns those who attend the follow up clinics ill and toxic and often with the history of continuous expectoration of purulent sputum These patients have an empyema which can be detected by radiological examination followed by a thoracentesis which reveals the pus Although most common after pneumonectomy for cancer

occasionally a late empyema follows lobectomy for bronchiectasis and tuberculosis Such a condition was common in the old days of tourniquet lobectomy, when the state was referred to as a "stump abscess" An abscess round a broncho-pleural fistula is dangerous because it may lead to severe infection, atelectasis and bronchiectasis of the remaining lobe

Treatment Prophylactic measures include good technique at the operation and the immediate post-operative re-adjustments already described After pneumonectomy high negative pressures in the early phase after operation should be prevented this requires frequent radiological examinations and the re-adjustment of pleural pressures by the aspiration of blood and air If the pneumonectomy space has been drained by an intercostal catheter this should not be allowed to drain continuously as it increases the negative pressure and removes the valuable cushion of air within the closed hemithorax Such intercostal drainage which has as its object the removal of post-operative effusions should be intermittent, the clip on the rubber tubing leading to the water-sealed bottle being relaxed at intervals and removed after 48 hours Drainage is not employed in Birmingham after pneumonectomy, the fluid and air contents being controlled by aspiration

At the close of each aspiration intrapleural antibiotics are injected into the pleural space.

Fistulous development after lobectomy is rare it is seen occasionally when the remaining lobe fails to expand quickly to fill the hemithorax Its chief preventive treatment is good technique in stump closure, and measures used to obtain rapid re-expansion of the remaining lung tissue

The late development of an empyema after total lung resection could best be avoided logically by using thoracoplasty afterwards This should be done after resection for tuberculosis but many surgeons shrink from its performance after the lung has been removed for cancer

The treatment of a broncho-pleural fistula depends on the mechanical and septic complications Both require attention and treatment which varies according to the time at which the complication arises. The minor and major methods of treatment may be summarized as

Conservative—Drainage by intercostal catheter or needle aspiration combined with antibiotic therapy

Operative—(*a*) Immediate thoracotomy with closure of the fistula with or without drainage and with antibiotics.

(*b*) Thoracoplasty, with or without drainage

The least frequent in use, immediate thoracotomy is reserved for the early fistula, diagnosed quickly and before infection has taken place By this means a bronchial opening due most likely to faulty technique in bronchial suture can be dealt with before purulent and fibrinous deposits around the area have made such a formal operation unlikely to succeed * The later fistula, unless due to malignant necrosis of the bronchus stump, is usually dealt with by thoracoplasty after the pleural space has been drained Finally treatment will be influenced according to whether the preceding operation was a pneumonectomy or a lobectomy

The conservative method of treatment is the one with the widest application Kent (1950) recorded 13 fistulae with empyema that were successfully treated by rib resection

* Special precautions, as outlined on page 252, must be observed if dangerous "flooding" into the bronchial tree is to be avoided In addition, oxygenation of the patient may be impossible unless "one lung" anaesthesia or temporary blockage of the fistula is maintained by the surgeon

drainage and antibiotics without the use of thoracoplasty In our own series the results have not been so good and thoracoplasty has been used in over half the patients

Before a decision is taken as to the methods to be adopted bronchoscopy is of considerable help especially in the pneumonectomy group of patients by it information can be obtained as to whether malignant recurrence is the cause Some estimate of the size of the fistula can be obtained and from time to time the cause of the alarming symptoms of cough and slight haemoptysis can be seen as a partially extruded suture which can be removed

If a fistula has caused an empyema after pneumonectomy the aim should be to aspirate the pleural cavity to dryness if possible and proceed as soon as possible to thoracoplasty such a thoracoplasty has better chances of closing the pleural space if employed early than if used after a long period of drainage after rib resections If the fistula has developed



(a) (b)

Fig 5-3

(a) A post pneumonectomy empyema has been drained.
(b) The same patient after thoracoplasty which has obliterated the empyema space

early in pneumonectomy cases and has been re sutured thoracoplasty should be employed early Three patients have been dealt with in this way with success

A small fistula occurring early after lobectomy will often demonstrate its presence by auscultatory methods and by an increase in the size of any residual pneumothorax on the radiograph the future course of the patient will depend on the state of aeration of the remaining lung tissue If this can be re-expanded fully the fistula will become sealed off Temporary intercostal drainage should be re-instituted at once and bronchoscopy done if the remaining lobe is atelectatic

Quite exceptionally there is a case for re-suture of the lobar stump where drainage bronchoscopy etc fails to re-expand the remaining lobe If neither of these methods succeed and the remaining lobe fails to re-expand a total empyema will develop which all too often requires residual lobectomy and thoracoplasty for its cure

Cardiac arrhythmias after pneumonectomy

In addition to extrasystoles after pneumonectomy, more serious irregularities are not uncommon complications Massie and Valle (1947) examined 120 patients after pneumonectomy and found eleven examples of arrhythmia, five being auricular fibrillation, four auricular flutter, one with extrasystoles and one with ventricular fibrillation

An important factor seems to be age, for it rarely appears after pneumonectomy in patients below the age of 40 , nor does it bear any special relationship to the pre-operative electrocardiographic picture or to post-operative complications such as haemothorax or broncho-pleural fistula. Intrapericardial ligation of the lung vessels would be assumed to cause post-operative irregularities but this is not borne out in practice , nor does it occur most commonly on the first day, the third day being the time at which most auricular fibrillations develop (50 per cent) It commonly affects patients with some emphysema in the remaining lung and therefore may have its causation in pulmonary hypertension Vagal irritation in patients with anoxaemia may be a responsible factor (Smith and Wilson, 1944) It is certain that division of vagal fibres without local anaesthesia during the course of pneumonectomy does not cause irregularities in patients under anaesthesia, for we have studied this point in over 200 pneumonectomies and no such irregularities have been noted though traction on the lung may cause extrasystoles and a fall in blood pressure

Treatment Provided there is no evidence of congestive failure, post-operative anaemia is treated with careful blood transfusion and oxygen therapy together with sedatives If the ventricular rate is fast, digitalis should be given at once , the leaf is preferable to Digoxin unless a real emergency exists, when the latter is given intravenously (1–1 5 mgm. as the first dose followed by 0 25 mgm at intervals of 3 to 6 hours) As soon as the pulse rate has slowed the drug is given by mouth in the usual leaf dosage and with the usual precautions Quinidine may be used both as a prophylactic measure and in the treatment of the established irregularities

If auricular flutter is present digitalis therapy is started at once in the hope that the irregularity will be converted rapidly to one of auricular fibrillation and large doses of the leaf should be given, 6–9 grains (400–550 mgm) followed by 6 grains (400 mgm.) and then 2 grains (133 mgm) at six-hourly intervals, the dosage should then be in the neighbourhood of 2 grains three times a day until the flutter has been replaced by fibrillation.

Pulmonary oedema after thoracic operations

This is perhaps the commonest cause of an unexpected death after major thoracic
surgery : although seen most commonly after such extensive interventions as thoracop
pneumonectomy and oesophagectomy in the elderly, it is the occasion of death
to time in young patients Such deaths are usually ascribed to left-sided
on not altogether substantiated grounds

Anoxia is probably the commonest cause leading to damage of the lung
The associated air hunger, the rise in carbon dioxide tension, the tachyc
in circulation time with a decrease in cardiac output all tend to produ
of the lungs and so encourage oedema as a result of obstruction
vascular bed Forced laboured breathing has a squeezing effect
presence of oxygen lack produces pulmonary transudation In

before the heart fails as was well shown in Starling s heart lung preparation many years ago and when severe pulmonary oedema is attributed to left-sided failure after major thoracic operations the explanation at best seems a makeshift one

As in the case of the arrhythmias oedema is seen most commonly in the elderly after long thoracic operations especially when carried out in the presence of lung emphysema and in patients with poor nutritional states if hypoproteinaemia is present the risks of its developing are increased as in patients after oesophagectomy for cancer An obvious avoidable cause is " over-chlorination by intravenous therapy and the problem is then one of mismanagement of the patient s water balance especially where there is pre-existent pulmonary hypertension

The thoracic operation itself is an important cause in war wounds of the chest severe injuries especially of a blast nature or severe lung trauma were often accompanied by an increase in the normal bronchial secretions which were often retained in the absence of effective cough which itself was inhibited by the associated pain If other injuries were present peripheral failure was sometimes treated too energetically by over transfusion The chief aim was to relieve thoracic pain by morphia and local intercostal anaesthesia and encourage the cough reflex Intratracheal suction either bronchoscopically or by a tracheal catheter was employed as early as possible oxygen therapy was valuable but only if the tracheo bronchial tree was free of gross secretions Double or triple strength plasma infusions were employed with disappointing results The orthopnoeic position should be adopted to lessen pulmonary congestion.

NUTRITION OF THE SURGICAL PATIENT

Many patients in the care of the thoracic surgeon show chronic malnutrition This is due mainly to obstructive states of the oesophagus or cardia of the stomach to severe wasting after prolonged fevers such as pulmonary tuberculosis or the general toxaemic states accompanying chronic lung suppuration

Intracellular and extracellular metabolism depends on a complex physico-chemical system characterized by the presence throughout of water in which are dissolved or suspended substances involved in the oxidation–reduction reactions This great transport system depends on the water with its crystalloid and colloid content supported by semi permeable membranes across which transfer of fluid and selected solids occur at varying rates Osmotic pressure gradients are the main motive force but some may follow active metabolic work. Response to losses and requirements for repair following injuries depend primarily on this exchange system from one area to another

Water electrolytes protein and blood cells make up the bulk of the aqueous medium and are our principal concern They are distributed in the body as in the table of Gamble (1951) on pages 98 and 99

To appreciate the enormous fluid exchanges that daily take place it is well to realize that each day 7 litres pass into the alimentary tract 2 litres are taken by mouth and 100 litres are filtered by the glomeruli of the kidney

The circulating blood along with the tissue fluids supply nutrition material to the cells and deliver up to the kidneys waste and excessive materials while they also serve to stabilize such physico-chemical conditions as ionic concentration osmotic pressure and temperature

Control of these processes is exercised by neuro humeral mechanisms in which the

endocrines, principally the pituitary and suprarenal, the liver and the kidneys, play the major rôles

The newer knowledge

For a full consideration of all the problems involved, the works of Gamble and Moore in the United States and Marriot in this country should be read

In addition to obvious losses of water and electrolytes, deficiencies of other substances are equally important in chronic malnutrition The diet must include all requirements for repair and rebuilding as well as meeting the calorie requirements If calories are deficient

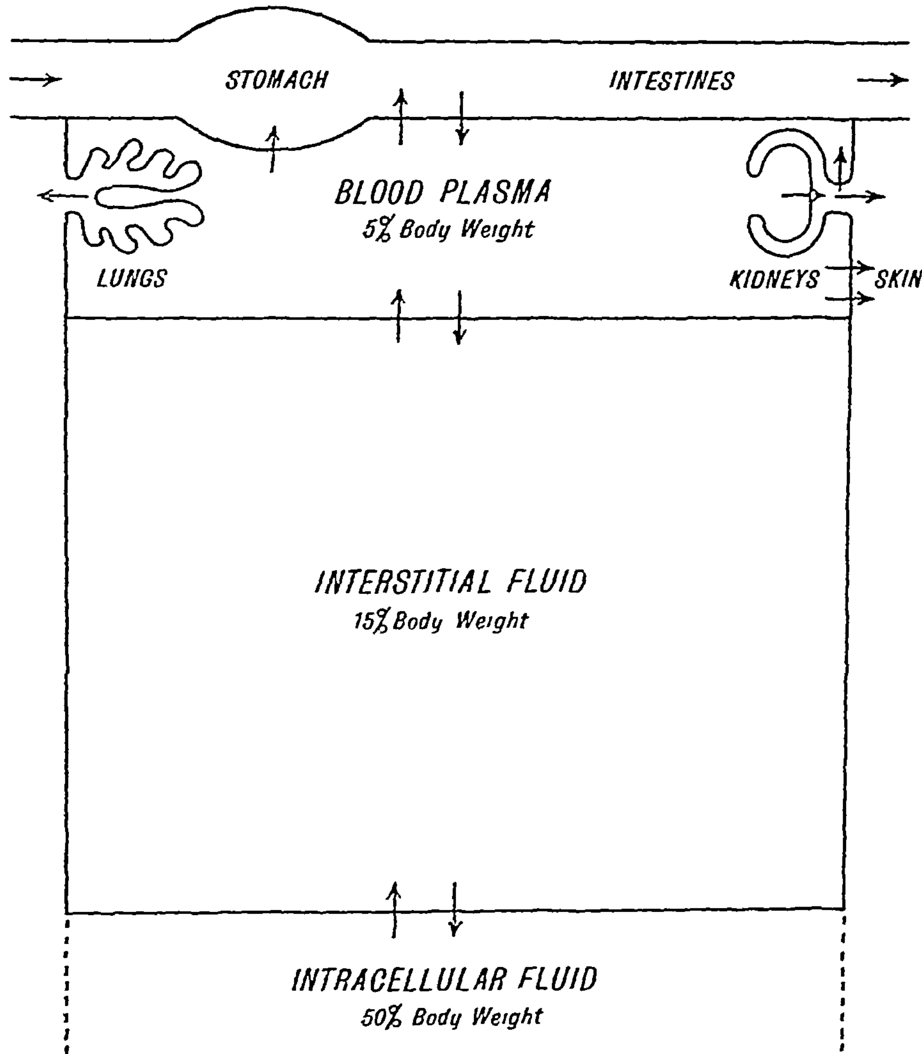


FIG 5 4

By kind permission of Dr J L Gamble

valuable protein is broken down for energy needs If the patient is eating normally it is easy to provide sufficient calories but in patients being nourished parenterally the problem is a difficult one. Glucose solutions, depending upon their rate of absorption and utilization and in the absence of gross spill over into the urine, can support the patient for a time If the recent use of intravenous fat emulsions (Mann, Geyer, Watkin and Stone, 1949) proves to be satisfactory this method will provide 1,600 calories

Nitrogen, for active rebuilding of protoplasm, is available in the form of amino-acid solutions or as whole protein where there is an acute need of osmotically active protein as in oedematous states where it may be life-saving. Much evidence has now been accumulated

that 50 per cent of the body albumin previously thought to be confined to the serum and the cells is actually in the tissue spaces and most particularly in viscera such as the lungs and the liver where the capillaries appear to be as permeable to albumin as to electrolytes This may explain some of the curious anomalies of ascites without peripheral oedema

Potassium is now well recognized as an essential requirement for active protoplasmic rebuilding Rarely its acute shortage in the serum with the consequent neuro-muscular disorders such as the cardiac arrythmias may produce an acute clinical emergency

Lastly a full understanding of the body's requirements for salt and the dangers of over-chlorination is important

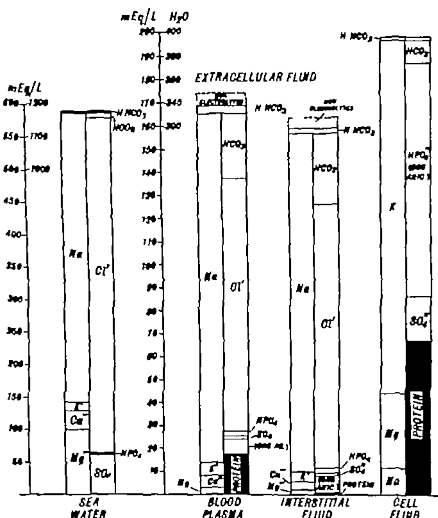


Fig 5-5

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The nutritional deficiencies

The nutritional deficiencies of the patient may be considered under several headings

(*a*) *Pure water deficit* This is not commonly seen post-operatively, but pre-operatively may accompany such conditions as oesophageal obstructions and coma The symptoms are those of thirst dry tongue loss of weight and a low urine output of high specific gravity There is a concentration not only of red cells but also of electrolytes and proteins in the extracellular fluid which may be partly demonstrated by the haematocrit value

(*b*) *Pure salt deficit* This is seen under conditions where a mixed salt and water loss is compensated for by water only as in the severe sweating states and in the post-operative administration of water only or as glucose solution to a mixed deficiency Addison s

disease, particularly in a "crisis", can provide an excellent example of this condition The result to the organism is a loss of total osmotic pressure in the extracellular fluid and as a consequence the kidneys excrete the water taken in an endeavour to maintain normal osmotic relations The clinical picture is characteristic—a moist tongue with an absence of thirst in fact there is often a natural antipathy to the taking of further water which is "protective" Vomiting may be present, as may be muscular cramps The patient shows severe dehydration with circulatory failure and a urine output which may be quite good The peripheral failure is due to the low circulating blood volume, with a low tissue fluid volume, but there may be oedema of the cells since the intracellular electrolytes do not escape across the cell membrane easily Hence the absence of thirst and the presence of a moist tongue

(c) *Mixed water and electrolyte deficit* This is the common condition where a loss of extracellular fluid and electrolyte occurs while no water is being taken The causes are such conditions as *vomiting, diarrhoea and alimentary fistulae* The effect on the patient is proportionate to whichever of the two components predominate, water deficiency is usually due to unavoidable insensible losses As a result there will be a reduction in the extracellular fluid volume accompanied by a degree of hypertonicity. Symptoms will be a mixture of those of pure salt and pure water deficiency—general lassitude, asthenia with thirst, dry tongue, oliguria and low blood pressure There may be a differential loss of base or acid ions, for example vomiting causes a loss of chlorine ions leading to alkalosis whereas in diarrhoea or intestinal fistulae there is loss of sodium ions leading to acidosis, correspondingly the ionic concentration of the plasma alters.

Water, electrolyte and protein losses affect the autonomic functions of the alimentary tract, which may undergo dilatation and atony causing further vomiting, gastric dilatation and ileus, conditions which may produce a vicious circle effect in the post-operative period.

(d) *Whole blood deficit* Along with high intestinal obstruction and large surface area burns, haemorrhage produces the most rapid form of dehydration However, in haemorrhage, the losses of water and electrolyte are small compared with the total water and electrolytes in the body, but the loss of red cells is proportionally large and rapid death may take place following large haemorrhages unless the blood is replaced rapidly Moore (1949) has pointed out that the importance of the red cells depends on their particulate size which confines them entirely to the circulating blood space, unlike the proteins and electrolytes Upon this large space-occupying property depends to a very great extent the blood volume, the cardiac output, and hence the blood pressure Nutritionally, too, their loss is of great importance, since they contain one-tenth of the total potassium and one-twelfth of the total nitrogen in the body This loss is handed on to other tissues, especially the bone marrow, for their priority re-manufacture, to the detriment of the rest of the organism

If the red cells are inadequate the oxidative processes cannot proceed normally and rapid permanent damage to such essential structures as cell membranes and capillaries, particularly the liver and kidneys, may take place and may well be responsible for the condition clinically recognized as "irreversible shock"

Large losses of nitrogen demonstrated by negative nitrogen balances are common, for example in starvation states associated with obstructions of the upper alimentary tract Balance studies have shown that initial losses are of the order of 10 grammes of nitrogen a day for the first few days, followed later by a steady daily rate of loss of 7 grammes Examination of the serum protein values rarely shows evidence of hypoproteinaemia because of the equivalent losses of water and electrolytes with consequent decrease in blood volume Danger exists when re-hydration occurs without recognition of this fact and the blood

proteins may be reduced to a dangerous level Acute forms of hypoproteinaemia may be seen in such conditions as closed loop obstructions and severe inflammatory conditions of the peritoneum or pleura. Severe nitrogen losses are also associated with such conditions as chronic pulmonary suppuration with or without an associated albuminuria and must be recognized Following severe trauma, Moore found that there is a daily high nitrogen excretion of 12 to 16 grammes lasting 7 to 10 days In a previously healthy patient no untoward effects result but in a chronically depleted individual slow recovery poor resistance to infection defective wound healing or oedematous states may result

Peripheral oedema is rarely met with and then only where total blood proteins are very low but visceral oedema is much more common and is important to the surgeon as anastomotic suture lines may be endangered and lead to obstruction delayed healing or leakages

Intestinal tone and peristalsis are also adversely affected by low levels of proteins and therefore may be contributing factors to the post-operative dilatation and atony

Potassium deficit Recognition of the importance of potassium is relatively new and we are indebted to such authors as Professor Elkinton for much of our knowledge of this subject Potassium is the essential base for intracellular metabolic processes Consequently following cell breakdown in malnutrition and in adaptive processes to trauma potassium is liberated and excreted Similarly when active rebuilding of cell protoplasm is required potassium must be available as an essential material Acute forms of intracellular potassium deficiency also follow acute losses of water and electrolytes as in infantile diarrhoea and vomiting In such a condition far greater amounts of water and potassium are lost from the cells than nitrogen indicating intracellular dehydration without protoplasmic break down In both the above states the serum potassium levels are usually normal

Extracellular potassium deficiency does occur but is much more uncommon it may be associated with the acute losses as above or in more chronic states often in association with alkalosis with low chloride high bicarbonate and normal serum sodium levels This is explained by sodium-potassium shifts across the cell membrane A similar condition has also been described following the treatment of diabetic coma with insulin and glucose the rapid laying down of intracellular glycogen causes a corresponding acute potassium shift from the extracellular space

Clinically its recognition is of great importance the patient suffers from general muscular asthenia hypotonia and cardiac irregularities and the electrocardiogram is often diagnostic This state of extracellular loss responds rapidly to potassium infusions

Diagnosis of the nutritional deficiencies

At present exact scientific methods of assessing nutritional deficiencies are inadequate The history and clinical condition of the patient are the best guides combined with assessment of the fluid and electrolyte losses due to any acute disorder such as vomiting Where the patient has been under observation for some time as in the post-operative period fluid and electrolyte balance charts where the measurement of both these factors in the fluid lost e g vomit or the leakage from fistulae into the chest or from gastro-oesophageal anastomoses will be made Add to these the insensible losses from the skin and lungs of approximately 1 000 c c per day and an excellent basis for restorative therapy exists Occasionally biochemical measurements are of great help

The serum sodium level is utilized by many as a guide in severe losses but it must be remembered in the less severe losses that good functioning kidneys will preserve osmotic pressure by excreting water and thus apparently normal values may be found Similarly

serum potassium estimations are sometimes very helpful In both these cases the use of the flame photometer will provide a very easy and rapid answer.

Plasma hydrogen ion concentrations and serum bicarbonate estimations are excellent where changes such as acidosis or alkalosis are suspected, particularly where a breakdown in respiratory (due to intracranial lesions, drugs, emphysema) or renal control occurs

Changes in body weight, if an efficient simple method were available, would be of great help in assessing losses of total body water

Measurements of urinary chloride or better still sodium output per day is still believed to be a very useful control test This, of course, always presupposes that a normal renal function and normal suprarenal and pituitary control are present and that there is no upset in plasma hydrogen ion concentration, facts which sometimes cannot be taken for granted

In the absence of any pre-operative nutritional deficit convalescence after major surgical trauma should be left to the natural adaptation processes, coverage for fluids as required for renal function and " insensible " losses only being required In the future the employment of such a test as that of the " adrenocortical function " devised by Thorn *et al.* (1948) will no doubt be used, this depends on the eosinopenic response to adrenalin or adrenocorticotrophic hormone and *is a measure of the patient's apparent resistance to surgical or other trauma*

Replacement therapy

In uncomplicated cases, as has already been stated, the body's only requirements are those of 1,000 c c of water a day to cover obligatory losses and the basal requirement of between 1,300 and 1,500 calories per day which may be given, for example, as glucose 300 to 350 grammes In this way starvation with the resulting breakdown of proteins for energy purposes can be spared The route employed should be the mouth whenever possible but as so often happens this may be impossible, making the taking of these basal requirements difficult *Glucose solutions in greater concentration than 10 per cent thromboses veins and leakage takes place via the kidneys if the administration is too rapid, 0 5 gramme per kilo of body weight per hour seems to be maximum* The use of intravenous fat emulsions *therefore has a place here when they become generally available*

Electrolyte administration should only be sufficient to replace losses Normal saline has long been the routine electrolyte solution used, but *it must be remembered that it is* isotonic only with the red blood cells and contains excessive amounts of the chloride ion which with a poor renal function is likely to upset hydrogen ion concentration values The use, therefore, of a true physiological saline is recommended this may be made up as follows 0 64 gramme NaCl, 0 25 gramme $NaHCO_3$, 0 0018 gramme KCl The well-known Hartmann's solution is equally good, containing additional buffer in the form of lactate Both these solutions are isotonic with tissue fluid, and contain all the essential bases including potassium to compensate for the continued inevitable renal losses of the base, and to provide extra essential rebuilding materials for the cells Where renal damage is severe, for example in anuria, the provision of electrolytes and particularly potassium may be dangerous, leading to cardiac arrest

Acute blood losses must always be made up by immediate equivalent transfusions. *Any delay enables plasma volume to be made up from the tissue spaces so that late transfusions may increase the normal blood volume leading to embarrassment of a heart with a low reserve* Thanks to the work of Wangensteen (1942) and Gross (1949) we now have a method of measuring blood losses during operation, since it enables minimum losses to

be known at any time thus enabling correct compensation to be made The only possible blood substitute on a more than temporary basis is dextran which has a particulate mass of roughly the same size as the red blood cell.

The infusion of plasma except in acute osmotic disturbances for example where local oedema occurs post-operatively has little to recommend it Intravenous protein is only slowly utilized by the tissues as an available source of nitrogen and in addition plasma always carries the risk of homologous serum jaundice Amino-acids administered intravenously however have a place in the treatment of protein deficiencies their greatest disadvantage being that slow rates of infusion are necessary otherwise a gross spill over into the urine occurs

The rate of intravenous administration It has been customary in surgery for many years to force fluids but more recently the dangers of this particularly where 0 9 per cent NaCl solutions are used have been realized and most surgeons would agree that a slight fluid deficit is better than any degree of excess However rapid intravenous administration may occasionally be justified for example as suggested by Marriott (1947) in acute circulatory failure due to salt, or mixed water and salt, deficiency The administration of 3 to 4 litres in the first 24 hours may be necessary under these circumstances Acute whole blood losses must be equally rapidly replaced

Dangers of over-chlorination The kidneys represent the most important safeguard for water and electrolyte therapy the statement that given water and salt the kidneys will excrete the excess differentially as required is so nearly true as to have become dangerous when we realize that patients can be and are killed by its use The reason for this is that the kidneys are often by no means normal and their ability to concentrate and excrete chlorides is depressed In children elderly patients and chronically debilitated patients this is usually the case

In addition to this an obligatory degree of salt retention occurs post-operatively which is exaggerated by the administration of saline (Moore) and thus the kidneys are unable to excrete excess salt The normal salt intake varies from 5 to 10 grammes per day

A second important point is that water administered with salt in isotonic solution is tied and is not available for the replacement of fluid lost by evaporation or in the urine Therefore if the kidneys are to provide free water they have to excrete urine containing a higher concentration of saline than that administered if they are unable to do this oliguria or even anuria may result

Oedema particularly pulmonary oedema is therefore the natural result of over chlorination and may produce a rapidly fatal issue aggravated by the associated anoxic effect on the tissues and their capillary permeability Lesser degrees of oedema such as those found around operation sites anastomotic suture lines and wounds will delay healing and interfere with the physiological function of the parts.

Lastly the administration of isotonic saline solution will produce dilution of proteins and red cells in the serum.

Summary

Electrolytes should not be administered except to replace known or suspected clinical losses

Free water must always be provided to replace insensible losses and to cover renal function This should be given by mouth wherever possible but can be supplied intravenously as solutions of glucose

In cases of malnutrition in its widest sense, provision must be made for water, calories, nitrogen and electrolytes, the latter to include both essential bases, sodium and potassium.

Vitamins

Vitamins are no longer reserved for the cure of certain rare diseases but are known to be essential for normal cell metabolic processes Sub-clinical deficiencies are common. Their lack may be responsible for such conditions as delayed wound healing and poor resistance to infection In addition it is widely recognized that many surgical procedures in themselves may cause vitamin deficiency diseases, as in the instance of gastric resections precipitating a gross vitamin B complex deficiency

Vitamin A deficiency is uncommon in surgery but it is usual where there is evidence of general malnutrition to give vitamin A, as we know that it plays a definite part in resistance to infection

The vitamin B complex is of great importance because it is known to be essential for tissue respiration. The principal deficiencies met with in surgery seem to be the fractions thiamine, nicotinic acid and riboflavine, although whole B complex should always be administered These deficiencies appear to be particularly high following modern radical gastric resection as described by Brain and Stammers (1951)

Gross vitamin C deficiency in the adult population is now almost unknown, but the association of subclinical deficiency with poor wound healing and anaemia is common Vitamin C appears to be responsible for the maintenance and production of intercellular substances, for example collagen, bone matrix and the intercellular tissues of capillaries Poor wound healing due to vitamin C deficiency is recognized throughout surgery

Fat-soluble vitamin deficiencies in surgery are rare but special mention might be made of vitamin K deficiencies which are met with in jaundiced patients, and in addition vitamin K may be used to correct the unduly low prothrombin states brought about by certain anticoagulant drugs such as Dicoumarol or Tromexan.

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PART II

THE SURGERY OF PYOGENIC INFECTION

CHAPTER 6

EMPYEMA

Though defined simply as a pleural effusion that is frankly turbid purulent and with a high cellular and protein content characteristic of an exudate empyema is represented by many different grades of severity and extent dependent on the state of the underlying lung pathology and the nature of the organism A turbid effusion developing early during the course of a pneumonia treated adequately by sulphonamides and antibiotic therapy is often cured by aspiration and the use of drugs and suitable antibiotics but once pus with fibrinous deposits has formed surgical treatment is usually advisable to prevent chronicity continued sepsis and crippling of the lung and chest wall function Treatment by aspiration chemotherapy and surgery are along the same lines whether the empyema belongs to the syn pneumonic type usually streptococcal or the meta pneumonic (pneumo coccal) empyema

Treatment by antibiotics and sulphonamides has so altered the whole natural history of pneumonia and its sequelae that the previous differentiation of empyema into those that develop early in the pneumonia and those that follow the start of the lysis is of less significance now playing little part in diagnosis or treatment

It will be most unfortunate if aspiration combined with antibiotic therapy (local and general) is regarded as an alternative treatment to surgery In early pleural infection after gun shot wounds it was clear that penicillin could sterilize many empyemata (d Abreu Litchfield and Thomson 1944) but did not always enable the products of infection to be totally removed when this happened lung and chest wall function could become per manently crippled Surgical and antibiotic therapy must be employed coincidentally in many patients with pleural infection

The newer conceptions of treatment

The modern treatment of pleural empyema is designed to abolish infection produce full lung re-expansion and to avoid a rigid chest wall or an empyema scoliosis of the spine These aims are easy to achieve if the diagnosis is made and the operative measures accurately timed The surgical treatment of an empyema is never an acute emergency but is based on deliberate planning after a full clinical bacteriological and radiological assessment

Since the time of Hippocrates when empyema was treated by drainage many wars have aroused the interest of surgeons in pleural infections and the apparent conflict between the need for opening the chest to evacuate the pus and the dangers of open pneumothorax have only been banished by the events of the last war Chemotherapy physiologically sound anaesthesia and adequate surgical technique have abolished the fears of producing an open pneumothorax in an infected pleural cavity The insistence by Evarts Graham (1918) that open pneumothorax should be avoided in patients with thin streptococcal

effusions was based at that time on sound physiological and pathological principles moreover, the clinical test of ignoring his advice was reflected in a mortality rate of 80 per cent when open drainage was performed in early streptococcal empyema accompanying a pneumonia Today, the dangers to which he drew attention can be overcome by scientific management of the empyema Graham and Bell showed that open drainage performed before encapsulating adhesions and a stiffening of the mediastinum had developed, seriously upset the sound lung because of the transmission of a positive atmospheric pressure through a mobile mediastinum , and the onset of paradoxical breathing in a patient with a low vital capacity and open pneumothorax was fatal If the pleural cavity is to be opened safely we now know that the mediastinum can be steadied, as was done many hundreds of times during the last war for the treatment of early infection of a haemothorax, by the anaesthetist controlling respiration so that active mediastinal movements do not follow

The chemotherapeutic control of toxicity in streptococcal empyema has greatly decreased the illness of these patients and helped to maintain a reasonable vital capacity At the same time the intrapleural injection of drugs has allowed the inflammatory process to proceed along lines far more akin to the fibrin-producing effects of pneumococcal infections and decreased the delay before operative drainage or decortication can be done.

Etiology and pathology

Inflammation of the pleura is always secondary, the infective process spreading to it, from the lung in most instances but occasionally from injury, from sub-diaphragmatic abscess, from osteomyelitis of the spine or ribs or as part of a septicaemia The same pathways of infection are seen in tuberculous disease By far the commonest type of pleural infection in civil life accompanies or follows pneumonia (syn-pneumonic or meta-pneumonic empyema), possibly the result of the rupture of a small sub-pleural abscess Pleural infection however produced, arouses the usual response of acute inflammation and the process may resolve completely or by repair fibrosis (commonly causing pleural adhesions) or may proceed to suppuration A fibrous or dry pleurisy is the commonest manifestation but a sero-fibrinous or " wet " pleurisy is frequently met with in practice Such effusions are usually straw-coloured exudates with or without a high leucocyte content and depending entirely on the defensive powers of the body, natural or bolstered up by chemotherapy, organisms may be present or absent

With the increased survival rate of patients with acute pneumonia due to antibiotics and chemotherapy the number of serous effusions has increased If the infecting organisms die the effusion will resolve and this is common, but it is important to remember that an effusion proved to be sterile at the first aspiration may subsequently become infected and sufficiently slowly to be overlooked in the absence of obvious pyrexia Clinically this may be emphasized by realizing the numbers of patients who are now diagnosed as having pleural empyema when attending out-patient departments as ambulant apyrexial convalescents. The intensive chemotherapy practised in the acute stages of the pneumonia may have exerted a bacterio-static rather than a bactericidal action, followed by a slow, undramatic recrudescence

When the pleural exudate is grossly turbid and purulent an empyema exists The fluid is more viscous, has a higher specific gravity with an obvious increase in protein, cells and frequently organisms even at this stage natural resolution, aided by complete aspiration and chemotherapy, especially if employed intrapleurally and parenterally, is possible but the complacent assumption that this will follow is most unwise Unless the infection is eliminated completely and the lung re-expands fully a fibrino-thorax may develop, which

if not diagnosed and treated may produce constriction of the lung and loss of chest wall movement with permanent damage to respiratory function

The effects of inflammatory pleurisy

Resolution may be so complete in all types of pleurisy that loss of the potential pleural space may not follow though this does occur in most instances in varying degrees Even after a pleural empyema has been drained surgically the major part of the pleural cavity may remain free and I have seen an artificial pneumothorax produced for the treatment of a tuberculous process that developed in a patient who years previously had been successfully treated by surgical drainage for a pyogenic pleural empyema

More usually obliteration of wide areas of the pleural space follows the organization of the fibrin deposited on both the visceral and parietal pleurae This pleurodesis may diminish the lung function on that side and a complete fusion of the parietal and visceral pleura interferes considerably with respiratory function. If these surfaces are kept apart by pleural fluid as in the type of quiet empyema that may follow inconclusive penicillin therapy the fibrinous deposit may be gross both on the chest wall and visceral pleura In the absence of absorption with lung re-expansion or of surgical treatment it becomes rap'dly organized on both surfaces in from two to six weeks after the start of the infection The invasion of the fibrinous deposit by small capillaries and their associated fibroblasts paves the way to true fibrous tissue the contraction of this tissue constricts the lung and cripples diaphragmatic and chest wall function by preventing the usual respiratory excursion The prophylaxis of the pathological process is by the operation of early empyema drainage and pleural toilet sometimes combined with lung decortication which will be discussed later Even after many months or years of this process the fibrous envelope on the lung and parietal pleura can be removed surgically through a plane of cleavage that can be developed between the new false membrane and the true pleura Although histological examination of this constricting layer shows that fibrous bands do spread deeply into the true layers of the pleura the membrane has a capacity for resisting the complete cirrhotic invasion of its shiny blue surface and this can be demonstrated easily during the operation of decortication

The shape and location of pleural effusions

In large effusions the empyema may be total filling a large part of the hemithorax compressing the lung and displacing the mediastinum to the opposite side even large empyemata may however produce no such displacement (see Fig 6 7) More usually the empyema is basal the fluid collecting in the costal sinus and spreading upwards and outwards towards the axilla (Fig 6 1)

Encapsulated empyema may provide apical interlobar or parietal collections of pus (see Figs 6 2 and 6-5) Since a lung released from compression either as the result of aspiration or drainage may expand unevenly in the early stages bizarre shaped empyemata of complicated shape may be seen If the base of the lung expands before the apex an hour-glass shape may result and this may provide difficulty in the post-operative management of a drainage tube which may have to be inserted higher and higher into the apical pocket Before decortication was used in the infected haemothorax of warfare these multilocular cavities were common On other occasions the empyema may have anterior and posterior compartments calling for drainage of each separately The shape and character of the empyema may be altered by the development of a broncho pleural fistula which

produces a fluid level on the radiograph (see Fig 6 4), a faulty diagnosis of lung abscess may result



Fig 6 1 —Left basal empyema (pneumococcal)
There is still consolidation of the lower lobe

Complications of an undrained persistent empyema

The clinical features of "chronic" empyema are reflections of the pathological process if not drained the empyema may rupture into the lung (broncho-pleural fistula) or on to the parietes (empyema necessitans) The diaphragm, the pericardium and the oesophagus have a strong resistance to the spread of inflammation beyond their membranes, though such a process is a rare cause of pleuro-oesophageal fistula When an empyema necessitans develops its external site is not always over the area of the maximum content of the pleural empyema and the pus may track along the plane of intercostal vessels to find egress from the pleural abscess commonly the site is placed anteriorly on the chest or anterior abdominal wall

The development of a broncho-pleural fistula is undesirable for through it re-infection of the empyema space frequently recurs and is a cause of chronic empyema, the spread of pus through the fistula may set up lesions in the same or opposite lung General toxaemia with severe secondary anaemia and the visceral changes associated with chronic sepsis develops, and cerebral abscess may become a complication In amyloid disease associated with pleural sepsis there is usually an associated tuberculous process

Bacteriology of acute empyema

The achievement of chemotherapy has largely obliterated the clinical differences that used to be a pronounced feature of empyema due to differing organisms in previous days a streptococcal infection frequently produced a thin sero-purulent effusion with greater toxicity than that following a pneumococcal one with its thicker, fibrinous pus It is common now to find large quantities of fibrin in a streptococcal empyema that has been fully treated by chemotherapy and the response of streptococcal infection to these agents is so rapid that gross toxaemia is rare

Staphylococcal empyema, once so serious in the absence of an efficient chemotherapeutic

substance is usually a sequel of septicaemia and the co-existence of multiple lung abscesses especially in infants and children is notable Their response to penicillin streptomycin or aureomycin is usually good and after the initial stages the course of an empyema in these patients may not differ from other pyogenic pleural infection though drainage is sometimes avoidable when they complicate staphylococcal pneumonia (see p 132)

The putrid empyema

This the most serious of all pleural infections is caused by a multiplicity of organisms many of which are symbiotic such as the Vincents organism pyogenic organisms are usually present and the *B coli* may be recovered The pus has a foul odour and is usually brown or greyish in colour Quite the commonest focus is from a rupture of a lesion in the lung parenchyma such as abscess suppurative pneumonitis or bronchiectasis The condition is seen as a terminal event in carcinoma of the lung when abscess or lung gangrene has developed distal to a blocked bronchus Putrid empyema will not respond to chemotherapy alone and is the one empyema that calls for early urgent surgical treatment The underlying pathological processes such as bronchial carcinoma or lung abscess make the use of bronchoscopy an important preliminary examination in patients of carcinoma age urgent pleural drainage is indicated and in patients with spreading suppurative pneumonitis pleuro-pneumonectomy may be indicated.

The effect of chemotherapeutic and antibiotic substances on the natural history and bacteriology

Although most of the patients with empyema who reach a surgical ward have been receiving chemotherapy this is not invariable and effusions typical of the causative organism may be present The severe toxaemia that accompanies a streptococcal empyema is associated with a thin purulent effusion free from fibrin and therefore unlikely to have fixed the lung to surrounding areas open drainage of such thin pus will be dangerous because of the movements of the mediastinum during and after the operation and it was this factor that led Evarts Graham to condemn early operation the principle then enunciated still holds good in this type of patient but must not be extended to cover the group of patients who have been treated by penicillin and who in addition to an absence of toxaemia and low vital capacity have thick pus in their pleural cavities The war time results after wide thoracotomy for clotted infected haemothorax empyemata have dispelled the idea that such major operations are dangerous in the presence of pleural infection (Churchill 1945) The modern management of streptococcal empyema which usually accompanies the pneumonic process is to sterilize if possible the lung the blood stream and the pleural cavity before recourse is made to operation the chief aim of which will be to remove the products of the now benign empyema and to restore full lung re-expansion

Diagnosis of empyema

Apart from infection after trauma or major intrathoracic operations the diagnosis is based chiefly on the knowledge that the patient has been or is suffering from a lung infection and on physical and radiological examinations the accuracy of which is confirmed by a thoracic paracentesis Reliance cannot be placed upon the classical features of syn pneumonic or post pneumonic effusions because drug and antibiotic therapy of serious or potentially dangerous respiratory infection suppresses or alters many of the signs and symptoms Rare indeed is the temperature chart which shows recrudescent pyrexia

following the abrupt fall in temperature after a dramatic crisis or lysis, because the chemotherapeutically treated lobar pneumonia seldom shows much pyrexia after 48 hours Nor is the malaise that used to accompany the raised temperature so distinctive and the patient may well be progressing to a hastened convalescence before the chest is noted to be moving badly and before dullness to percussion over an insidiously developed effusion is detected A more usual clinical picture is that convalescence is slower than hoped for and is marked by symptoms such as lassitude, cough and slight pyrexia The deceptively slow course of the disease favours the opinion that a chest radiograph should be taken before the patient is allowed to resume normal duties after a pneumonia

Frequently there is no shift of the mediastinum to the healthy side, for large effusions can collect without displacing either the trachea or the apex beat dullness to percussion and the absence of vocal and tactile fremitus are more reliable physical signs Poor movements and retraction of the ribs over the involved area are common Breath sounds may be heard through purulent effusions, especially in infants and children If any doubt exists as to the diagnosis radiographs in the postero-anterior and lateral position must be taken, but this step should be substituted by an exploratory aspiration under local anaesthesia if X-rays are not available In hospital practice it is inexcusable to forgo radiographic examination, for not only does it confirm the extent of the effusion but may disclose a hitherto unsuspected but causative disease in the thorax

The *technique of aspiration* is too well-known to call for description, but fluid is often withdrawn after previous failures by observing a few simple rules, the chief of which are the avoidance of too low a site for aspiration in the usual posteriorly placed effusion, the necessity for an accurate counting of the ribs when the fluid is in the more unusual sites such as interlobar, anterior or apical collections and the use of a really wide-bore long needle At each diagnostic and therapeutic aspiration care is exercised to prevent the entry of air into the empyema cavity, for its addition increases the rate of absorption of pleural fluids which may be serious in early infected toxic purulent effusions The entry of large quantities of air will lead to the further collapse of the lung and so defeat one of the chief aims of treatment, lung re-expansion The accident of air entry can be prevented by the use of a two-way tap on the syringe or of Potain's apparatus

Radiological appearances of empyema

Typical basal empyema The basal opacity in the usual uncomplicated empyema has a margin that slopes up to the axilla with medial compression of the lung (Fig 6 1), the lowest part of the effusion on the right side cannot be seen, usually because it fades off into the diaphragmatic surface of the liver shadow, but on the left side the stomach gas bubble usually enables an estimate of it to be made The same radiological appearances will naturally accompany a tuberculous or simple effusion and the differentiation can only be established on the history and the examination of a withdrawn sample of fluid

Encapsulated empyema Many patients with this condition may be ambulant for several weeks before progressive disease makes them seek medical advice The radiograph shown in Fig 6 2 was taken of a woman of 45 who had been treated five weeks previously for pneumonia at home and attended the out-patient clinic because of " anaemia " This fact and the radiological appearances may give rise to confusion with other space-occupying lesions and suggest diagnoses such as tumour, abscess or consolidation of lung parenchyma and lung cysts occupied by fluid In the last condition secondary infection may so complicate the picture that surgical drainage of a cyst may be carried out under the belief that an empyema is being drained. Such an error may lead to a continual chest wall fistula but

I know of two occasions on which drainage has been followed by alarming haemorrhage from incision of the large abnormal vessels that may supply such cysts

In the surgical management of encapsulated empyema the wall of the cavity must be inspected with great care a biopsy being taken to make sure that ciliated columnar epithelium is not present Error in diagnosis is possible when the cyst has an open bronchial connection the operator thinking he is dealing with an empyema complicated by broncho pleural fistula

The oval encapsulated empyema may simulate the appearance of thoracic neurofibroma or even of hydatid cyst

Interlobar empyema may be confused especially with a collapsed right middle lobe the usual error being to regard the atelectatic segments as an interlobar effusion Clinical



Fig 6· —Large encapsulated empyema (pneumococcal)

confusions over the recognition of interlobar effusions are accentuated by the commonly accepted assumption that most of these encapsulated empyemata have their origin in a ruptured lung abscess that has secondarily involved the space affected (Neuhof and Copleman 1941)

The natural history of encapsulated empyema is that many follow the rupture of a local lung abscess into the pleura after limiting adhesions have developed to prevent a spread of the inflammatory process If the adhesion formation is incomplete a bilocular or multi locular abscess cavity may develop separated at times by a considerable distance

Associated with encapsulated empyema may be a co-existent serous effusion para centesis of the clear effusion may confuse the diagnostic picture the circular or ovoid empyema being regarded as a neoplasm or other intrapulmonary lesion which has caused a pleural effusion

The characteristic radiological appearances of these enclosed empyemata include an oval outline the base of which is adjacent to the chest wall or diaphragm (see Fig 6 2)

If there is a broncho-pleural fistula or air has been introduced at paracentesis a fluid level will be present Such an appearance may lead to a faulty diagnosis of lung abscess Perhaps the most important radiological feature of encapsulated empyema is the sharpness of the margins seen, and the same applies to parietal empyema

Although the localized empyema is usually sited laterally or in the main fissure or against the chest wall (parietal empyema) it may be detected radiologically at the apex of the pleura, or at its mediastinal surface or between the base of the lung and the diaphragm In the rare para-cardiac type confusion may result in a diagnosis of enlargement of the heart or of pericardial effusion.



FIG 6 3—Complicated empyema

Note basal empyema and fluid level below left clavicle In the lateral radiograph this lay anteriorly Both empyemata were drained separately

Empyema with broncho-pleural fistula Bronchial connections with an empyema produce a fluid level in most instances, the condition may be confused with that of lung abscess (Fig 6 4) The differentiation can be made by a careful study of the segmental distribution of the lung, lung abscess rarely traverses the boundaries of its own segment and on the lateral radiograph its fluid level does not reach across the whole pleural cavity which is often the case with an empyema

Unusual but important causes of empyema Each year a few patients are seen with pus in the pleural cavity that has its origin in actinomycotic lesions of the lung or as the result of serious lung disease, the most common examples of which are carcinoma or other obstructions of the bronchus, lung abscess, bronchiectasis or tuberculosis (Fig 6 5)

The management of acute empyema

The evacuation of the empyema, the re-expansion of the compressed lung to obliterate the empyema space, the restoration of lung and chest wall function and the destruction or



(a)



(b)

Fig 6·4 (a) and (b)

(a) Pyo pneumothorax with broncho pleural fistula
(b) The lateral radiograph



Fig 6·4 (c)



Fig 6·5

Fig 6·4 (c).—A week later than X rays shown in Fig 6·4 (a) after simple drainage (closed)
The tube is still in position.

Fig 6·5 —Parietal empyema
The right lower lobe is collapsed as a result of bronchial adenoma. (Dr [illegible] Taylor's patient.)

neutralization of the infecting organisms are achieved simultaneously Chemotherapy and the use of antibiotics (locally and parenterally) usually subdue the infection and in the early stages of the disease they are combined with thorough aspiration of the purulent fluid It is unwise to believe that most infected pleural effusions can be cured by aspiration, combined with chemotherapy, there is the mounting evidence that this line of treatment when conducted half-heartedly is often followed by severe chest crippling, the result of retention within the pleural cavity of large masses of fibrin which prevent the full restoration of lung and chest wall function For this reason aspiration and chemotherapy alone rarely produce a perfect result Nevertheless once the physician or surgeon has commenced aspirations for the treatment of an empyema he must aim at a cure by this method providing he is ready to employ surgery if the aspiration method does not produce a rapid cure

Indispensable controls in the aspiration-chemotherapy treatment of acute empyema The treatment can only be carried out if radiological control is available and aspirations are carried out on alternate days until cure has been achieved The patient is given systemic penicillin (or the antibiotic appropriate to the organism) with a daily dosage of 2,000,000 units. At the first aspiration a complete evacuation of the infected fluid should be aimed at, and 100,000 units of penicillin in a few c c of fluid should be left in the pleural cavity The withdrawn fluid is sent for bacteriological examination and for testing for penicillin sensitivity On the following day postero-anterior and lateral radiographs are taken and the extent of the empyema visualized The aspiration is repeated on the following day and a further 100,000 units of penicillin is left in the pleura If the bacteriological tests have reported an organism that is insensitive to penicillin or other antibiotic agents, cure by aspiration alone is unlikely and the patient is warned accordingly If the organisms are sensitive to chemotherapeutic agents the aspirated fluid will usually become sterile after the third or fourth aspiration if the technique has been thorough, in addition the fluid will become more serous at each aspiration, with the radiographs showing a rapid lung re-expansion

Throughout the period of aspiration careful physiotherapeutic care is essential, active breathing exercises and repeated postural corrections designed to prevent scoliosis being practised frequently

After four to five aspirations an assessment of the progress is made If the withdrawal of fluid becomes increasingly difficult due to frequent needle blockage, if the chest wall movements remain poor and the radiograph shows evidence of fibrin formation, usually denoted by multilocular fluid levels, operation is indicated Surgical treatment is required if the organisms are insensitive to the chemotherapeutic agents available and the pus is thick Although few patients can be cured by aspiration and chemotherapy alone, when employed the attempt must be thorough and determined and it is an excellent way of preparing a patient for safe surgery

Surgical drainage of an empyema

To avoid the dangers of chronicity this must be adequate and not delayed too late Intercostal drainage is unsatisfactory, except as a temporary measure after decortication of the lung (see Fig 6 7(*b*)), its use before the pus is thick enough for rib-resection drainage can be avoided by adequate aspiration, in the presence of thick pus it is inefficient because of the frequency of tube blockage If the patient has been seen early in the disease and the time for drainage well selected, rapid lung re-expansion will follow simple rib resection

and drainage If on the other hand for some reason the drainage has been delayed the more extensive but highly satisfactory operation of decortication may be employed (Fig 6 7)

The operation of rib resection This is best performed under local anaesthesia consisting of posterior intercostal nerve block over three to four ribs combined with infiltration of the skin and muscles in the line of the proposed incision The site for the resection is estimated accurately by a rib count made on the radiographs and by a preliminary needling of the chest under local anaesthesia In selecting the rib the empyema cavity should be drained almost but not quite at its lowest point if the extreme lowest point is selected difficulty may be experienced later as the diaphragm invariably rises after the operation The injection of a small quantity of lipiodol after preliminary aspiration provides exact radiological evidence of the base of the empyema cavity

The technique of rib resection is on orthodox lines (see p 73) if the rib is exposed by a vertical rather than an oblique incision this allows the tube to lie more comfortably and enables one of two or three spaces to be needled before the selected rib is resected

After a generous segment of rib has been divided the intercostal vessels and nerves should be ligated and cut this prevents pain and may remove a risk of septic thrombosis spreading back along the vein to the spinal veins and upwards to produce cerebral infection (Leigh Collis 1944) The opening through the posterior intercostal bed and the pleura should be free the pus within the cavity is sucked out and all fibrin clots removed The cavity must be exposed fully so that no unexplored loculi are overlooked A large bore tube is then placed into the cavity

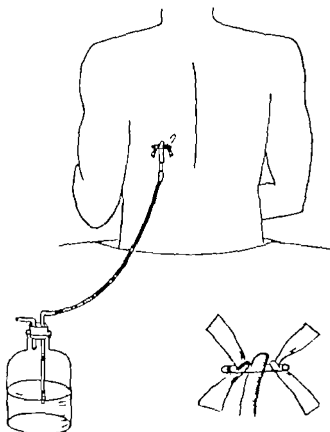


Fig 6-6 —Closed drainage to a water-sealed system. The smaller drawing indicates the method adopted for securing the tube by means of a safety pin and adhesive strapping.

Closed drainage is preferable except in a small localized empyema as it diminishes the number of dressings and re-establishes a negative intrapleural pressure An open tube however allows more vigorous physiotherapy to be employed the methods of tube fixation are shown in Fig 6 6 A flanged tube is not in favour because its withdrawal is *painful* and it cannot be manipulated easily if post-operative radiographs indicate the need for alteration of its position

Thoracotomy and decortication Increasing use of a wider thoracotomy a complete removal of all pus and fibrinous masses combined with a decortication of the lung gives admirable results The rapid lung re-expansion is so notable that many of these patients are up and well a week after their operation at the Queen Elizabeth Hospital this more extensive procedure has largely replaced the drainage of empyema after resection of a small portion of rib and the results have been very satisfactory The operation is similar to that described for decortication in tuberculous empyema (p 252) but the exudative membrane

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After four to five aspirations an assessment of the progress is made If the withdrawal of fluid becomes increasingly difficult due to frequent needle blockage, if the chest wall movements remain poor and the radiograph shows evidence of fibrin formation, usually denoted by multilocular fluid levels, operation is indicated Surgical treatment is required if the organisms are insensitive to the chemotherapeutic agents available and the pus is thick Although few patients can be cured by aspiration and chemotherapy alone, when employed the attempt must be thorough and determined and it is an excellent way of preparing a patient for safe surgery

Surgical drainage of an empyema

To avoid the dangers of chronicity this must be adequate and not delayed too late Intercostal drainage is unsatisfactory, except as a temporary measure after decortication of the lung (see Fig 6 7(*b*)), its use before the pus is thick enough for rib-resection drainage can be avoided by adequate aspiration, in the presence of thick pus it is inefficient because of the frequency of tube blockage If the patient has been seen early in the disease and the time for drainage well selected, rapid lung re-expansion will follow simple rib resection

and drainage If on the other hand for some reason the drainage has been delayed the more extensive but highly satisfactory operation of decortication may be employed (Fig 6 7)

The operation of rib resection This is best performed under local anaesthesia consisting of posterior intercostal nerve block over three to four ribs combined with infiltration of the skin and muscles in the line of the proposed incision The site for the resection is estimated accurately by a rib count made on the radiographs and by a preliminary needling of the chest under local anaesthesia In selecting the rib the empyema cavity should be drained almost but not quite at its lowest point if the extreme lowest point is selected difficulty may be experienced later as the diaphragm invariably rises after the operation The injection of a small quantity of lipiodol after preliminary aspiration provides exact radiological evidence of the base of the empyema cavity

The technique of rib resection is on orthodox lines (see p 73) if the rib is exposed by a vertical rather than an oblique incision this allows the tube to lie more comfortably and enables one of two or three spaces to be needled before the selected rib is resected

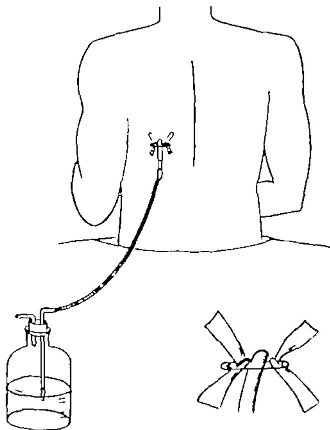


FIG 6-6 —Closed drainage to a water-sealed system. The smaller drawing indicates the method adopted for securing the tube by means of safety-pin and adhesive strapping.

After a generous segment of rib has been divided the intercostal vessels and nerves should be ligated and cut this prevents pain and may remove a risk of septic thrombosis spreading back along the vein to the spinal veins and upwards to produce cerebral infection (Leigh Collis 1944) The opening through the posterior intercostal bed and the pleura should be free the pus within the cavity is sucked out and all fibrin clots removed The cavity must be exposed fully so that no unexplored loculi are overlooked A large bore tube is then placed into the cavity

Closed drainage is preferable except in a small localized empyema as it diminishes the number of dressings and re-establishes a negative intrapleural pressure An open tube however allows more vigorous physiotherapy to be employed the methods of tube fixation are shown in Fig 6 6 A flanged tube is not in favour because its withdrawal is painful and it cannot be manipulated easily if post-operative radiographs indicate the need for alteration of its position

Thoracotomy and decortication Increasing use of a wider thoracotomy a complete removal of all pus and fibrinous masses combined with a decortication of the lung gives admirable results The rapid lung re-expansion is so notable that many of these patients are up and well a week after their operation at the Queen Elizabeth Hospital this more extensive procedure has largely replaced the drainage of empyema after resection of a small portion of rib and the results have been very satisfactory The operation is similar to that described for decortication in tuberculous empyema (p 252) but the exudative membrane

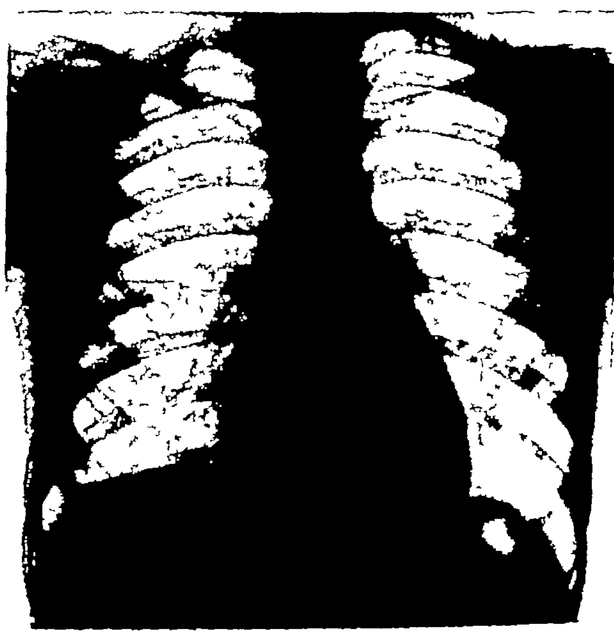
over the visceral and parietal pleura is softer and peels readily In the post-operative treatment two catheters, one apical and one basal, as first advocated by Price Thomas and



(*a*)



(*b*)



(*c*)

Fig 6 7

(*a*) Right total empyema (pneumococcal) treated by pulmonary decortication
Pre-operative radiograph

(*b*) The day after decortication
Portable radiograph showing the apical and basal intercostal catheters in position

(*c*) Full lung re expansion
Radiograph taken two months after that of Fig 6 7 (*b*)

Cleland (1945), in the treatment of clotted haemothorax, are used and connected to a small motor that provides continuous suction, as the aim is to produce full and rapid lung re-expansion.

Post-operative management

The chief aims are the maintenance of free continuous drainage and the rapid rehabilitation of lung and chest wall function by physiotherapy In a closed system of drainage constant attention must ensure that the system is efficient and that the column of fluid in the tube that leads beneath the water in the bottle moves up and down with each inspiration and expiration

The extent of lung re-expansion can be measured by radiological examinations but the temperature chart the rapid recovery of a sense of well being by the patient and the return of chest wall movements are all useful indications of satisfactory progress The tube site

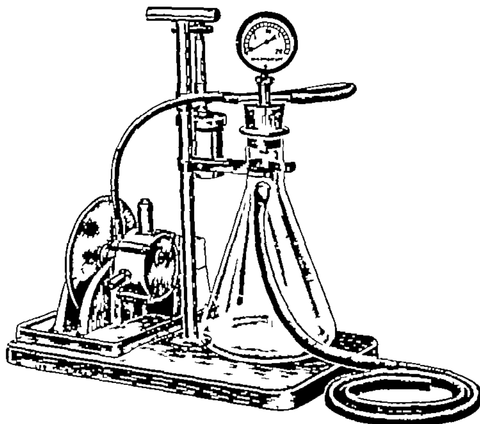


Fig 6·7 (d).—Roberts motor for providing continuous suction pressure (G U Mfg Co)

is adjusted according to the radiological appearances the empyema space may evolve into bizarre shapes because lung expansion is irregular In a large empyema the basal section of the lung often expands more rapidly than the areas forming the anterior and upper boundaries of the cavity and the tube must then be pushed up to a higher level to avoid the upper compartment becoming blocked off from the drainage opening

The empyema cavity may become hour-glass-shaped or bilocular with one pocket behind and one in front of the lung Such states may indicate the need for placing another tube more anteriorly or at a higher site after further rib resection The need for this can often be prevented by deciding at the time of the first operation to employ decortication instead of simple drainage Especially so is this when the pre-operative radiograph indicates the likelihood of post-operative difficulties from uneven lung re-expansion because of loculations due to pleural adhesions

When to discard the tube Injudicious removal of the drainage tube is the single commonest cause of "the chronic empyema" The tube should only be discarded when there is undoubted proof that the empyema cavity has been obliterated because the parietal and visceral pleura are in contact in all areas except along the line of the tube track This is detected most readily by studying pleurograms or sinograms obtained radiologically after the instillation of lipiodol into the "sinus" If both the lateral and postero-anterior views demonstrate that only a tube track is visible, the drainage tube is finally removed after gradual shortening



FIG 6 8—A sinogram

A large empyema has been drained the basal portions of the lung re expanded rapidly and the tube had to be inserted further in to provide drainage for the upper part of the empyema space The lipiodol-filled cavity is an indication for retaining the tube

The closed system can be dispensed with long before pleural symphysis has occurred and the patient is allowed out of bed at an early date

The wearisome repetition of this old story about the time for tube discarding is a duty that has its apology in the fact that most of the chronic empyemata referred to a Thoracic Surgical Centre recurrently indicate that the lesson has not yet been learnt universally

CHRONIC EMPYEMA

A definition of chronicity based on a time interval of a certain number of weeks is hardly related to etiology or to the therapeutic measures already tried, but perhaps an arbitrary rule to grade all empyemata of over six weeks' duration as "chronic" may be of value A persistent collection of purulent or fibropurulent material in the pleural cavity may follow late diagnosis, inadequate drainage or a lesion of the lung parenchyma such as fistula, bronchiectasis, lung abscess or new growth and these possibilities must be borne in mind when a chronic empyema is presented for treatment By far the most frequent cause of the condition is inadequate drainage of a post- or syn-pneumonic empyema and the blame may be attributed to delay in surgical evacuation and to the premature removal of the drainage tube before the parietal and visceral pleural layers have become adherent after full lung re-expansion

This being so the cure of the condition is usually by simple re-drainage at the correct site and the energetic pursuance of physiotherapeutic measures Sometimes these aims can be achieved more rapidly by the operation of decortication when the empyema is re-explored and this measure is in increasing use today

The object is to encourage lung expansion after or co-existent with the removal of the empyema contents, and a mutilating thoracoplasty should be avoided as long as possible and indeed is rarely employed in a thoracic department for chronic empyema, except after total pneumonectomy for cancer or tuberculosis when infection has followed

athology of chronic empyema

Whether drained or undrained the walls of an empyema steadily absorb fluid so that he cavity contents become thicker and thicker with a continuous deposition of fibrin on he parietal and visceral pleura and its infiltration by fibrous tissue which imprisons the ing and progressively diminishes the movements of the chest wall and the diaphragm Massive adhesions may turn the cavity into a multiloculated mesh in the pockets so formed ntrapped pus cannot reach the drainage tube or be removed by an aspirating needle This rocess not only leads to the deposition of thick masses but by preventing lung and chest vall function defies the natural tendency for cavity obliteration The cavity may be epeatedly re infected by organisms reaching it from an associated broncho-pleural fistula Persistent undrained infection leads to chronic ill health often without pyrexia and accompanied by a failure of bone marrow formation so that leucopenia may be present nstead of the expected leucocytosis Amyloid disease rarely develops unless there is an associated tuberculous infection Metastatic brain abscess may supervene and a spread of nfection through a broncho pleural fistula may cause a bronchopneumonic process in the contra lateral lung

The chest wall becomes progressively shrunken and immobile and the ribs approximate or overlap each other (tiling of the ribs)

The underlying lung though constricted may retain its normal appearance for many years but progressive loss of respiratory function is evident from studies performed after lung decortication in which little evidence of gaseous exchange can be obtained by the usual physiological tests even in the presence of a radiograph showing full re-expansion The lesion causing this may either be a fibrous replacement of the lung alveoli or an obstruction of the capillaries adjacent to the alveolar wall.

Other causes of chronicity Tuberculous disease actinomycosis and underlying lung diseases such as persistent collapse of a lobe bronchiectasis lung abscess suppurative pneumonitis and carcinoma are causes of chronicity and their existence may not be established until weeks or months after an empyema has been drained Naturally a higher proportion find their way to special chest units than to general surgical wards they are diagnosed by suspicion in a patient with an unusual clinical history and by careful examination of the radiographs supplemented by other examinations such as bronchoscopy bronchography and bacteriology Foreign bodies such as portions of drainage tubes or gauze are rarely seen and osteomyelitis of a rib in my experience has never been the cause of a persistent sinus but is the result of a persistent inadequately drained empyema

These unusual causes of chronic empyema must not allow us to forget that the cause in 80 per cent of the patients is delayed or inadequate drainage

The investigation of chronic empyema

The patient may present with evidence of an inadequately drained empyema usually with a sinus present through which pus inefficiently discharges from time to time or the chest wall may be intact as in examples of missed empyema these latter are by no means rare in these days of widespread chemotherapy which may have been given parenterally or intrapleurally or together The chief presenting symptom may be the expectoration of large quantities of purulent sputum and the patient may be regarded as suffering from lung abscess or *bronchiectasis*

The value of a careful history cannot be overestimated and from this a clue to the etiology is often obtained The story may disclose a long history of cough with sudden

development of serious illness, such is seen especially in patients with bronchiectasis or chronic lung abscess. In the older age group a history of cough, possibly with haemoptysis which preceded a "pneumonia" followed by an empyema, detected by radiology or thoracentesis, should at once arouse suspicions of a possible underlying bronchial carcinoma

A high proportion of the patients give a history of repeated breakdown of a sinus that heals and discharges intermittently and to which multiple local remedies have been applied Such a sequel of a drained empyema inevitably indicates an underlying inadequately drained empyema

A complete clinical examination is followed by radiological examination, a study of the bacteriology of the sputum and of any discharge from a chest wall sinus The radiological appearances are variable depending on the state of the empyema cavity at the time of the examination If no fluid level is present the condition may be erroneously diagnosed as thickened pleura The condition of "thickened pleura" should always be questioned when the patient under consideration is in poor general health or when attacks of "recurrent pneumonia" and pleurisy have been diagnosed, thus distracting attention from empyema This error is especially liable to be made when low-grade infection has involved a haemothorax, the sequel of a major intrathoracic operation or of trauma

The walls of a chronic empyema cavity may calcify Curiously this only appears to involve patients with a tuberculous infection or in those with a persistent low-grade infection in a haemothorax, the result of a gun-shot wound of the chest (Fig 6 9) Frequently a fluid level is seen, the air having gained access from a chest wall sinus, a broncho-pleural fistula or as the results of an aspiration

The state of the underlying lung is of prime importance In extensive, undrained empyema no details of the lung will be apparent If such an empyema is associated with total lung or lobar atelectasis, as in the case of a bronchus blocked by neoplasm, the trachea and mediastinum may be over to the side of the empyema instead of being displaced away from it Such an appearance indicates the need for bronchoscopy before treatment is directed towards the empyema

The radiological examination will disclose the extent of pleural thickening over the lung or chest wall and the degree of this may well decide whether simple drainage or lung decortication is to be practised, but such pleural thickening may rapidly absorb after adequate drainage and physiotherapeutic exercises

The bacteriological examination is essential though the basic infecting organism may not be detected at the first or subsequent examination especially so is this when the underlying process is tuberculous or actinomycotic and these two diseases should be in mind when a chronic empyema is being investigated, their possible presence is an important reason for performing a pleural biopsy at the time of the operation on the cavity

The extent of the cavity Sinograms taken after the instillation of iodized oil are helpful In addition to outlining the cavity which is usually larger on the lateral view than expected from the plain radiograph an unsuspected broncho-pleural fistula may be visualized. Since iodized oil is not entirely non-irritant it should be sucked out of the cavity after the radiographs have been taken The presence or absence of underlying disease of the lung may often be investigated usefully by means of bronchography and this examination is necessary if the history suggests a possible bronchiectasis Although iodized oil introduced into the pleural cavity often delineates a broncho-pleural fistula the reverse is not true and oil introduced deliberately into the bronchial tree rarely finds its way into an empyema cavity

Treatment of chronic empyema

Surgical measures The many operations designed for the cure of chronic empyema might obscure the essentials of treatment which are adequate drainage or total evacuation of the empyema together with decortication of the thickened supra pleural organized exudate and vigorous physiotherapy The use of thoracoplastic operations often combined with Roberts flap operation or the complete saucerization of the cavity are last resort measures so too are the operations designed for the surgical closure of a broncho pleural fistula following its isolation after dissection suture and an on laid muscle graft useful though this is in the occasional patient Most broncho-pleural fistulae will heal when the object of obtaining pleural symphysis has been achieved for the essential mechanism that maintains patency of such a fistula is the persistence of the empyema pocket



Fig 6·9



Fig 6·10

Fig 6·9 —A chronic empyema with calcified walls, the result of gun-shot wound in the 1914–18 war Patient seen in 1950 when this radiograph was taken.

Fig 6·10 —A chronic empyema with obvious thickening of the visceral pleura preventing lung re-expansion; an indication for lung decortication The empyema has been drained and the tube is still in place

The choice of operation The chief decision required is whether to employ adequate simple drainage or a wide thoracotomy incision through which pleural toilet and decortication can be effected. Simple drainage has proved to be highly effective but it may have to be prolonged many months and is difficult to execute when the empyema cavity is loculated although drainage at more than one site may be effective in bilocular empyemata when there is an anterior and posterior collection of pus In very ill patients simple drainage will be selected as the operation can be performed under local anaesthesia with little or no disturbance

Local thoracoplastic operations are effective for moderate sized cavities if the un-roo or "guttering" (Sellors and Cruickshank, 1951) is thorough The cavity in suitable patie may be packed daily until healing has followed from within outwards, or obliterated by method of J E H Roberts in which a large flap consisting of the thickened parietal ple and the intercostal bundles is fashioned by incisions above, below and anteriorly, leav the hinge posteriorly This flap is then placed in apposition with the visceral pleura maintained there by packing between it and the skin

Total thoracoplasty is rarely indicated except as already mentioned for empyema t has followed a pneumonectomy if the underlying lung is sound the operation of decort tion is indicated in the type of empyema illustrated in Fig 6 10 where evidence that a heal underlying lung exists if the lung is so diseased as to be valueless the operation of pleu pneumonectomy followed later by a limited thoracoplasty is likely to provide a better a quicker result than a total thoracoplasty executed in stages

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CHAPTER 7

LUNG ABSCESS

Changes in the natural history and treatment of lung abscess

Clinical experience and the records of the literature indicate changes in the natural history of this disease in the last decade Although still a potentially lethal disease it lacks its previous malignity its more favourable course possibly being influenced by the modern availability of effective chemicotherapeutic and antibiotic agents Together with a decline in severity a great fall of incidence has been noted in the last few years contributions on the subject of lung abscess in the world literature have diminished

For a long time surgeons criticized the prolonged delay before open drainage was considered Such delay was justified by physicians on the grounds that the mortality rate in patients treated surgically admittedly often in the late stages of exhaustion and toxaemia was as high as those treated expectantly (Maxwell 1934) Because of the brilliant results obtained by Neuhof and Touroff in 1942 by early surgery for putrid lung abscess the pendulum swung in favour of surgical treatment the delay being numbered in days rather than weeks before conservative treatment was abandoned. By common experience a conservatively treated lung abscess that progressed well did so rapidly usually after the sudden expectoration of much pus after several days of high pyrexia and gross constitutional disturbance whereas the long-drawn-out illness of a less fortunate patient left him ill fitted for surgical drainage at the oddly arbitrary period of six to eight weeks when the abscess was frequently complicated by surrounding septic pneumonitis and bronchiectasis The surgical cure of such a patient often called for lobectomy rather than drainage because of the irreversible damage to the surrounding lung parenchyma and bronchi

When the case for early drainage had been accepted conservative measures were abandoned after ten to twenty days if the abscess had not decreased in size in a patient clearly deteriorating the mortality rate fell dramatically as surgeons were presented with patients before the last stages of a fatal illness The fact that Neuhof and Touroff (1942) had only 4 deaths in 122 early operations for lung abscess established at that date the superiority of external drainage over hesitant expectancy aided by a mass of drugs of doubtful value Admittedly their figures were not approached by other groups of surgeons but even the more normal mortality rate of 15–25 per cent was a great advance over the previous one of 50–60 per cent *

In Britain opposition to over persistence in conservative treatment came chiefly and lucidly from Brock (1947) who not only criticized the high mortality rate of medical treatment but stressed the permanent pulmonary suppuration that often remained after a so called cure had been achieved The case for early external drainage rested on the general surgical principle that any abscess without natural adequate egress should be opened The recognition of the pathological fact that a lung abscess is peripheral in relation to the

* Touroff Nabatoff and Neuhof (1950) have published a valuable follow up study of 163 patients who were treated by early one stage drainage of whom 154 were operated upon in the pre penicillin era 113 patients were followed up for over five years of these 100 were completely cured with no symptoms and a normal chest radiograph or bronchogram 15 patients only were regarded as unsatisfactory because of doubtful lung radiographs or recurrent haemoptysis which occurred in 6 patients

lung segment it occupies, and quickly produces symphysis between parietal and visceral pleura immediately over the site of suppuration, altered the line of treatment The site of the abscess could be marked on the chest wall surface by an accurate counting and measurement of ribs based on a study of lateral, postero-anterior and oblique radiographic views of the chest, so that rib resection and drainage could be performed without violating the general pleural cavity because of its early local obliteration by adhesions Brock greatly influenced physicians and surgeons to adopt early drainage with improved results in the mortality and clinical cure rates and this method of treatment became the routine

During the last few years the introduction of antibiotic therapy has again changed the method of treatment Excellent results are now being achieved by large doses of antibiotics given parenterally and combined with postural drainage The surgical drainage of acute lung abscess has almost disappeared from the lists of surgical operations

When surgical treatment is used it consists largely of excision of segments, lobes or lungs that are the site of chronic disease, usually with septic pneumonitis and bronchiectasis in patients inadequately treated in the early phases of the disease One-stage drainage is still indicated for patients who do not respond to antibiotic therapy and are too ill for major resection operations A real and continued decline in the incidence of lung abscess is the interesting climax of this story and this may be explicable by a consideration of the etiology and pathology

Etiology and pathology

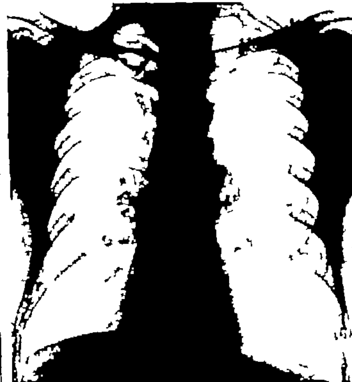
The location of lung abscess has a constancy capable of anatomical and pathological explanation Certain facts are established The right upper lobe is the commonest seat of acute lung abscess, followed by the right lower lobe as the next most frequent site If lung abscess was commonly a sequel of pneumonia or blood-borne infection this distribution would not occur, in blood-borne abscesses of the lung the distribution is often bilateral and multilobar (Fig 7 4) The commonest cause of solitary lung abscess is undoubtedly bronchial embolism as shown by Brock, gross obstruction of a bronchus by a growth or impacted foreign body is also a frequent cause, as discussed later these causes indicate the need for diagnostic bronchoscopy in patients with lung abscess

The usual lung abscess is due to a bronchial embolus much smaller than a gross foreign body such as a tooth The embolus is of such a size that it is sucked into a segmental bronchus and may not invade a whole lobe, its nature is usually infected muco-pus, blood clot after dental extractions or upper respiratory operations such as tonsillectomy or adenoidectomy or from particles of septic " tartar " inhaled from the back of septic unscaled teeth The inhalation of foreign bodies may be undramatic, in the early stages the patient himself being quite unconscious of such a major embolism, even more silent is the passage of muco-pus, especially as it takes place in the patient while in sleep, or unconscious from a general anaesthetic

The predilection for lung abscess development in the posterior (posterolateral) segment of the right upper lobe and the apical segment of the right lower lobe is well explained by Brock as a postural phenomenon During sleep, particles of matter flow into the right main bronchus more readily than the left, and since most people lie on the right side the material will first incline to the opening of the posterior segment of the upper lobe as this drains towards the axilla, and the clinical fact that lung abscess most commonly affects the axillary portion of this segment supports this view After general anaesthesia many patients are nursed flat on the back until consciousness is regained and in this position the bronchial embolus, be it blood clot, muco-pus or dental debris, tends to flow into the apical segment



(*a*)



(*c*)

Fig 7 1

(*a*) Consolidation and collapse of right lower lobe Pyrexia and offensive sputum ten days after extensive dental extractions.

The patient was referred as a possible carcinoma of the right lower lobe for a bronchoscopic examination. The tooth (Fig. 7 1 (*b*)) was not noted on the radiograph.

(*c*) A week after removal of tooth

Rapid clearing and re-expansion of right lower lobe.



Fig 7 1 (*b*) —Tooth removed by bronchoscopy from right lower lobe



Fig 7 2.—Lung abscess in posterior segment of right upper lobe

There had been a sudden pyrexial illness with cough a fortnight before this radiograph was taken; the dental condition was bad.

of the right lower lobe The fact that post-tonsillectomy lung abscess used to develop most commonly in the right upper lobe is explained by the custom of placing such patients on their right side until the effects of anaesthesia had worn off

The postural explanation of the site of abscess formation could be developed more fully but one fact remains to be noted If lipiodol is placed at the back of the nose before sleep, a radiograph taken the next day shows that the oil has gravitated into the sites rendered most dependent by the posture adopted by the sleeper as an example it will be found in the posterior segment of the right upper lobe if the subject, as is normal, sleeps lying on the right side (Amberson, 1937)

That the incidence of simple lung abscess is twice as common in men as women may be due to the greater male incidence of dental sepsis and the deeper amplitude of the breathing which may add to the dangers of inhalation

The easy access of particulate matter such as barium and iodized oil and of organisms to the lung bronchi under anaesthesia has been readily demonstrated in animals (Cutler, 1929) If the animals were maintained on planes of varied angles, substances placed in the mouth or nose could be recovered from the lungs if the head was on a plane above that of the body, quite irrespective of the depth of anaesthesia employed the aspiration effects were always abolished if the Trendelenburg position, even in its less exaggerated degrees, was used The clinical application of this to the human patient under anaesthesia indicates the constant vigilance required to correct dental and oral sepsis before operation and to take all means possible to prevent bronchial embolism, either by posture or by the use of cuffed intratracheal anaesthetic tubes or careful packing of the pharynx

Classification of lung abscess

Lung infection (pneumonitis) may resolve or proceed to suppuration or permanent structural damage such as bronchiectasis or fibrosis Usually the abscess is single but in

TABLE I

R C Brock (1950)

Identified causes (47 were due to bronchial carcinoma)	269
Obscure causes	94
	363

When the 47 abscesses due to carcinoma and the 94 cryptic cases were excluded, 222 patients were left for analysis

1 *Post-operative*	
Abdominal operations	41
Non-abdominal (these included 25 dental extractions and tonsillectomies)	39
	80
2 *Dental sepsis*	60
3 *Specific infections*	
Staphylococcus	21
Streptococcus	1
Friedlander's cases	2
Actinomycosis	2
	26
4 *Various causes*	
(including 16 upper respiratory infections and 13 lower respiratory infections)	56

blood infections may be multiple when it is due to specific infection such as the staphylo coccus streptococcus or Friedlander s bacillus Brock (1947) suggested a logical classi fication based on a group in which the causes are identifiable and on another in which the etiology remains debatable the primary cryptic type of abscess putting this classification to the test of exact analysis in 363 personal cases his findings were as shown in Table I on the previous page

It is of interest to note that a tooth or other inhaled foreign body in the bronchus was responsible for only 1 per cent of the abscesses whereas bronchial carcinoma was responsible for over 10 per cent

Such a classification is helpful because it indicates the need in early lung abscess for a full investigation which includes a careful history clinical examination bronchoscopy and bacteriological studies of the sputum and blood

Perhaps trauma should be considered as an unusual cause of lung abscess In 1 000 examples of gun-shot wounds of the chest (d Abreu 1947) only 32 developed proven lung abscess Occasionally a pulmonary infarct becomes infected with development of a lung abscess

Decline in the incidence of lung abscess

Apart from post-operative lung abscess the decrease may be attributed to a lessened incidence of gross dental sepsis In spite of a continued decline in dental health fewer teeth are seen with gross deposits of tartar and though many more are edentulous the increased number of people with dentures has lessened the risk of bronchial embolisms from dental sepsis Coincident with this improvement in mouth hygiene is the decline in foetor of sputum both in lung abscess and bronchiectasis an odour that was commonly noted in the earlier days of lobectomy for bronchiectasis This foetor was largely due to secondary infection from organisms commonly associated with neglected oral sepsis The potential danger of oral sepsis is recognized in thoracic departments and special pre-operative dental care is practised before operations such as resection of lung tissue or oesophagectomy

The post-operative lung abscess whether following upper respiratory operations or laparotomy has become rare When the vogue existed for operating on the tonsils and accessory nasal sinuses in the sitting up position and before cuffed intratracheal tubes and careful packing off of the pharnyx to prevent tracheo bronchial soiling became the routine lung abscess was not uncommon but increasing realization that after operations such as tonsillectomy blood was often found in the air passages if looked for through the broncho scope led to the adoption of preventive measures and this disaster is rare today The post laparotomy lung abscess due to bronchial embolism of upper respiratory or bronchial muco-pus has been almost eliminated by the careful bronchial toilet either by suction or bronchoscopic aspiration and by the general use of active lower chest movements and the encouragement of the cough mechanism after such operation The remaining few that develop could be eliminated largely if bronchoscopic aspiration of retained muco purulent sputum were practised for lower lobe collapses that do not clear with postural drainage and by the encouragement of deep breathing and coughing

Unconsciousness or coma as a cause Pulmonary abscess is seen from time to time in alcoholic patients after a long period of unconsciousness or in patients who have been in coma as a result of narcotics diabetes trauma or following immersion in water The combination of such periods of unconsciousness with gross dental sepsis especially in elderly social derelicts in poor general condition is an occasional cause of abscess formation

The bacteriological aspect

In simple lung abscess the etiological factor being bronchial embolism or aspiration, the infecting organisms may be of many different species, the development of the disease depends largely on the organisms which multiply distal to the segmental bronchial obstruction The ciliary action of the bronchial mucous membrane plays a part in ridding the unobstructed bronchus of infecting organisms and is aided by the normal cough mechanisms, in lobar or segmental collapse the upward transmission of organisms by the ciliary action towards the trachea is ineffective and they rapidly multiply The emboli are usually infected, e g blood clot, muco-pus, dental deposits, inhaled food or small foreign bodies and, as would be expected, the organism in a lung abscess consists largely of the pathogenic and non-pathogenic organisms commonly present in the mouth and upper respiratory system



FIG 7 3 —Staphylococcal abscess in an infant simulating a cyst or local pneumothorax This disappeared completely on penicillin therapy Staphylococci were recovered from the sputum

Aerobic and anaerobic organisms flourish Pneumococci are the most frequent invaders, but staphylococci, streptococci (especially the viridans group), micrococci catarrhalis, fusiform bacilli, spirochaetes and Gram-negative bacilli are often present A pure culture of one organism is not usual and there is no specific agent, though the great increase in the range of antibiotics enables most to be attacked The putrid lung abscess probably depends on a large content of anaerobes combined with spirochaetes and the fusiform bacillus these have a capacity for causing rapid tissue death and in the putrid abscess a large central slough is common most exceptionally the extension of this process may destroy a whole lobe (spontaneous lobectomy) Many of these organisms are sensitive to large doses of antibiotics there is evidence (Pile, 1950) that penicillin therapy when employed has often been along the lines of the classical dosage Pile believes this is inadequate and that at least two million units a day are required Since the spirochaetes are only secondary invaders and soon disappear when the abscess has either emptied into the bronchus or has been drained externally there is no case to be made for the use of arsenicals which in themselves may have depressing or toxic effects

Staphylococcal lung abscess or pneumonia Staphylococcal infection following a septi-

caemia is of special importance A pure staphylococcal empyema usually seen in children often indicates that a staphylococcal lung abscess has ruptured into the pleura But the most striking radiological appearances are seen in patients with multiple lung abscesses due to this organism these may be large in size (Figs 7 3 and 7 5) and tension in type often with obvious fluid levels The desperate appearance of the patient and of his X ray findings may suggest the need for drainage but this is an abscess where surgery is certainly contra indicated they respond well to massive penicillin therapy if the organism which may be recovered from the sputum or blood is penicillin sensitive If it is resistant, as proved by a study of the sputum content streptomycin aureomycin or chloromycetin should be used

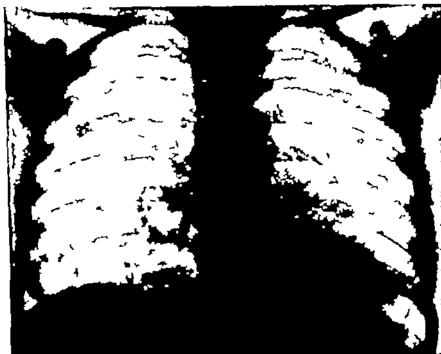


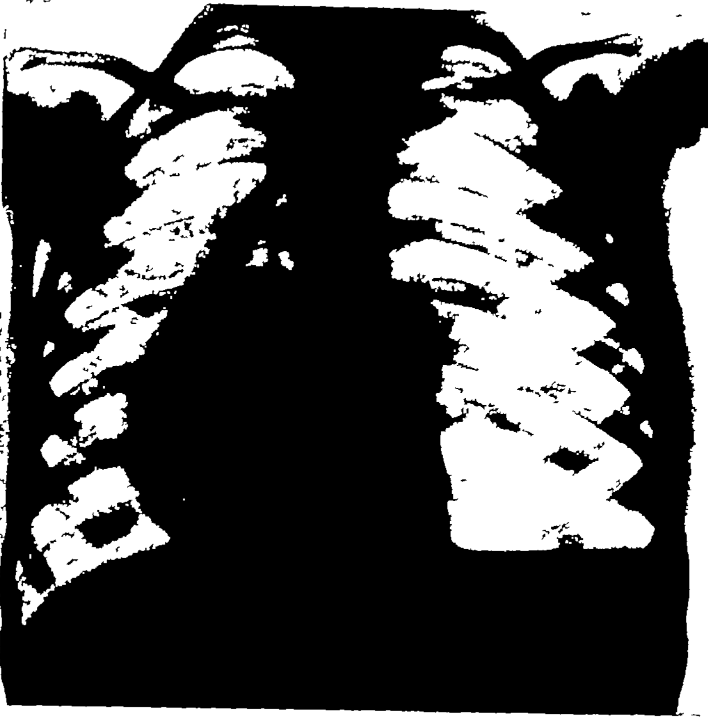
Fig 7·4 —Multiple staphylococcal lung abscess in the right lung in a child associated with a collapsed left lower lobe

Two of the abscesses are air-containing but the one in the upper lobe is solid. Staphylococci removed from the sputum. The right lung cleared completely under penicillin therapy

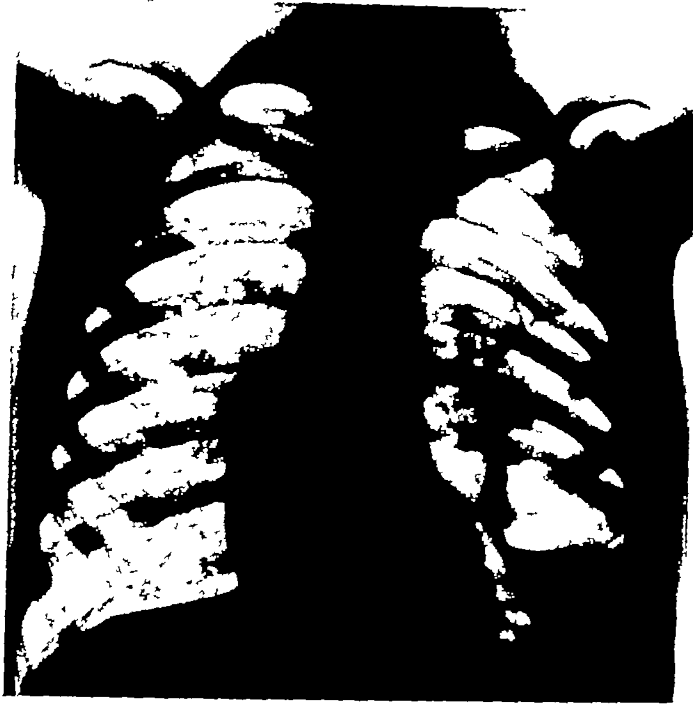
Occasionally these staphylococcal abscesses rupture into the pleural cavity adding considerably to the frightening appearances of the radiograph. In spite of such a complication the condition may resolve completely with antibiotic therapy combined with paracentesis of the chest if fluid collects in the pleural cavity The radiographs shown in Fig 7 5 illustrate the course of such a patient in whom only one aspiration of the chest was practised penicillin was given parenterally in two daily doses of half a million units for six weeks

After considerable clinical improvement the radiological appearance of a cavity may persist it may be mistaken for a congenital cyst localized emphysema or partial pneumothorax

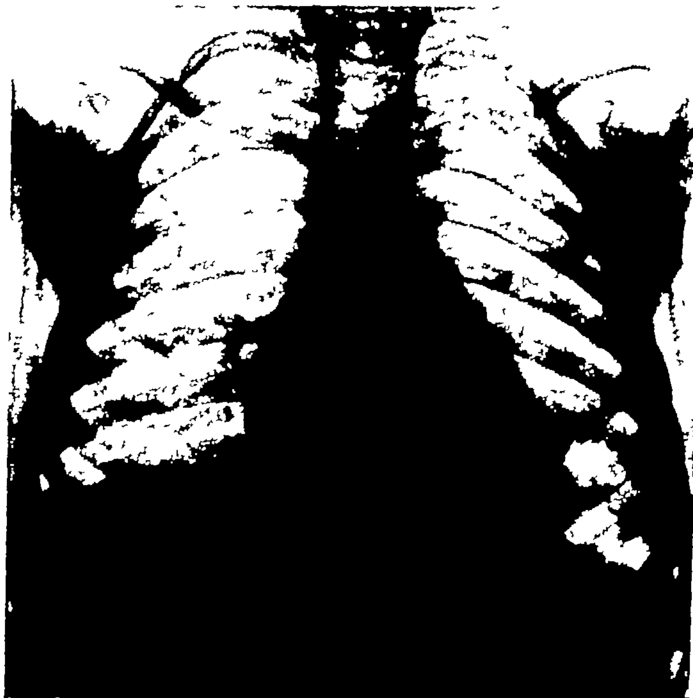
Rare infections Quite exceptionally lung abscess may be due to infection by Brucella tularensis or as a complication of Brucellosis my personal experience is confined to a patient with a pasteurella infection Actinomycosis as a cause should always be remembered the diagnosis may be made after a long illness in which the streptothrix is discovered in



(*a*)



(*b*)



(*c*)

Fig 7 5

(*a*) A child of four years admitted with high pyrexia

There is a left pyo pneumothorax (staphylococci recovered from aspirated fluid) and collapse of the left lung A circular abscess cavity is also present in the right upper lobe

Treatment was by parenteral penicillin continued for six weeks In spite of the alarming radiological and clinical condition recovery was complete

(*b*) After three weeks
(*c*) After six weeks

the sputum the prognosis is bad but not invariably fatal The treatment is intensive consisting of prolonged penicillin administration (8–12 weeks) with sulphamethazine given in full doses for three alternative courses of two weeks each potassium iodide is also used and when the process is efficiently counteracted deep X ray therapy with small doses over a long period is probably of value one patient treated in this way is well three years after the diagnosis was made

Pulmonary coccidioidomycosis

As far as I am aware this condition is not met with in Great Britain but increasing numbers of cases are being reported in America (Cotton and Birsner 1950) As cavitation appears in this disease its differential diagnosis from lung abscess and pulmonary tuberculosis is necessary in areas where the disease is liable to develop and is best made by finding the characteristic spherules in the sputum In treating this condition Cotton and Birsner used pneumonectomy segmental lobectomy or local resection with decortication and decortication with thoracoplasty Melick (1950) has published an interesting report based on 100 excisions performed by different surgeons in the United States

Histoplasmosis of the lung

Infection of the lungs by histoplasma capsulatum is being increasingly recognized and studied the granulomatous lesion produced by the histoplasma may affect all areas of the body In the lungs no specific pattern can be described but unilateral or bilateral infiltrations may lead to a wrong diagnosis of pulmonary tuberculosis or neoplasm on the radiological appearances occasionally cavities form and these may be regarded as lung abscess A discussion of the subject has been published by Hodgson Weed and Clagett (1950)

Lung abscess that is not ' simple '

Major bronchial obstruction Gross obstruction of a lobar bronchus by a foreign body such as tooth or meat bone causes infected atelectasis more commonly than a lung abscess (see Fig 7 1) but the possibility of an abscess being due to an obstruction must always be realized and simple abscess unless cured rapidly after expectoration of its contents should not be treated without a bronchoscopic examination this is especially so in chronic lung abscess and many of these in men over the age of 50 are due to bronchial carcinoma and serious errors will follow the neglect of bronchoscopic examination

Carcinoma of the lung apart from producing a lung abscess distal to its blocking effect on a bronchus may break down in the centre and give an appearance of lung abscess. The tumour that breaks down is usually a squamous epithelioma on radiological examination the walls of such an abscess are thicker than those seen in the true pyogenic state or a tumour mass is visible within the cavity

Pulmonary infarction Post-operative pulmonary infarcts may go through a phase of septic pneumonia leading to lung abscess and in addition to any measures used in the treatment of the thrombosis such as heparin or other anti-coagulants or ligation of the iliac vein or of the inferior vena cava chemotherapy should be instituted in all patients who survive a pulmonary embolus

Septic embolism Before the era of effective chemotherapy and the use of antibiotics pyaemia was not uncommon in many conditions such as osteomyelitis or peripheral sepsis Maxwell (1934) in a series of 116 multiple lung abscesses found that 62 had followed septic conditions elsewhere The abscesses will be multiple in most instances Of special interest

to thoracic surgeons are those occasionally associated with mycotic aneurysms of branches of a pulmonary artery in patients with infected patent ductus arteriosus

Lung abscess associated with subphrenic abscess The natural history and treatment of





Fig 7 6 Fig 7 7

Fig 7 6 —Squamous carcinoma of right upper lobe with a small air-filled cavity (Pneumonectomy) Note the solidity of the walls

Fig 7 7 —Carcinoma of left upper lobe in a man of 52 which has broken down into an abscess. Diagnosis confirmed by bronchoscopy and pneumonectomy

this is discussed in Chapter 27 The abscess more usually develops as a complication of collapse of a lower lobe than as a result of direct extension of the subphrenic inflammation across the diaphragm A noticeable exception to this is the spread of hepatic amoebic abscess (see p 578)

Complications of lung abscess

These may be local or general

Local complications The spread of the local process in abscesses that do not resolve naturally or with the aid of partial drainage and antibiotic therapy often produces a permanent bronchiectasis in the lobe affected

Increased tension within an undrained abscess may cut off the blood supply sufficiently to cause lung gangrene with the production first of a large slough followed later by death of the whole lobe In a few exceptional examples the whole lobe is sequestrated and at operation for empyema has been lifted out as a large necrotic mass (spontaneous lobectomy)

Unless the abscess disappears rapidly after the sudden expectoration of pus, a valvular mechanism often develops at the site of rupture into the bronchus, the communications

with the bronchus may be multiple and bulge into the abscess space As in tuberculous cavities air can enter the space more easily than it can escape because the fistulous openings are oedematous and in the normal process of expiration become narrowed this is accentuated by the inflammatory thickening of the bronchial fistulae This mechanism is illustrated by the specimen shown in Fig 7 9 of a right upper lobe removed for a lung abscess which shows the pouting bronchial openings into the cavity

The rupture of an abscess into a pleural cavity is a serious complication and is the usual cause of putrid empyema Local extension to the pericardium is unusual but may cause septic pericarditis

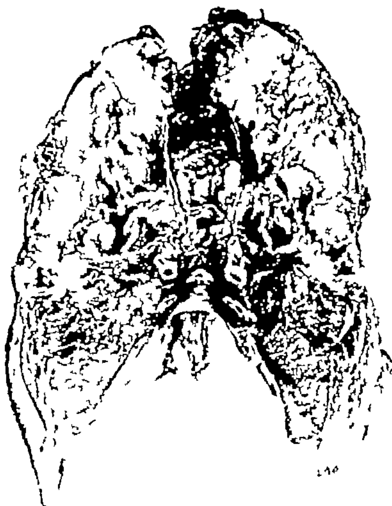


Fig 7 8 —Operation specimen.
Extensive structural alteration around chronic lung abscess cavity; note also the dense thickening of the visceral pleura.

General complications In addition to general toxaemia and quite rarely of amyloid disease septic thrombophlebitis may cause a cerebral abscess or meningitis and the recognition and prompt treatment of this condition is important as there now exists hope of recovery for these previously doomed patients The neurosurgical treatment of metastatic cerebral abscess by antibiotic therapy diagnostic ventriculography exposure and aspiration of the effusion and later excision of the encapsulated infection is followed if possible by resection of the affected area of the lung and notable recoveries have been published after this attack on thoracogenic cerebral abscess (Pennybacker and Sellors 1948)

The development of neurological signs pointing to a cerebral abscess is occasionally

the result of a cortical cerebral venous thrombosis and this may be seen at the cerebral exploration J M Small has diagnosed this in four of my patients with suppurative lung conditions and all recovered.

Clinical features

History Patients who develop an abscess while in hospital have usually had surgical operations on the upper respiratory system, the mouth or the abdomen followed by an uneasy convalescence In this group and in those who commence their illness at home the story is rarely a typical one Malaise, a commencing rigor and a high sustained pyrexia often precede cough and expectoration, pain in the chest is usually localized to the intercostal space overlying the affected segment If the first sputum expectorated is foetid in odour



Fig 7 9

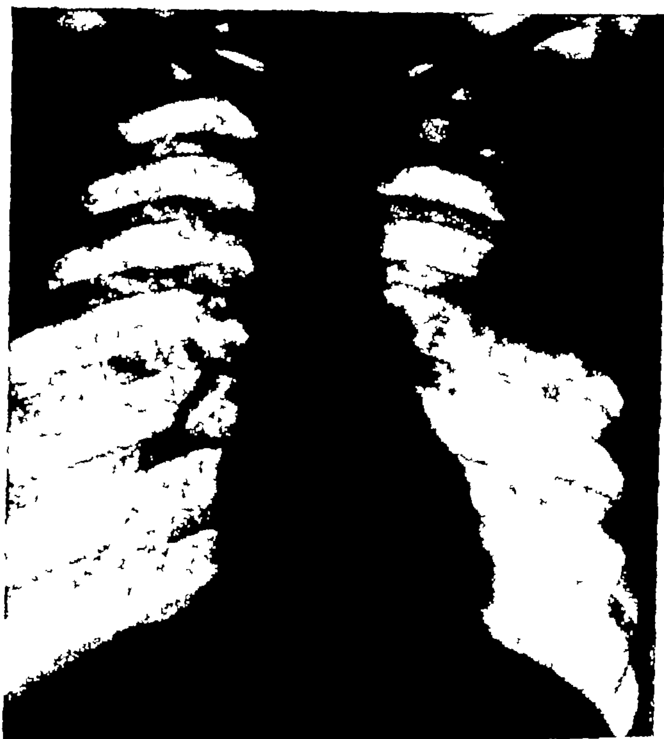


Fig 7 10

Fig 7 9 —The interior of a lung abscess from a lobectomy specimen showing the inadequate drainage through multiple pouting bronchial fistulae

Fig 7 10 —Radiograph of a lung abscess with early cavitation

a diagnosis may almost be made on this alone This symptom may be preceded by a bad taste in the mouth and the breath may be offensive before there is any actual sputum The high temperature, the sudden prostration and the pleural pain often lead to a diagnosis of "pneumonia", but in the early days of lung abscess the short ineffective cough is usually absent and dyspnoea is not a marked feature Haemoptysis is frequent and often precedes by a few hours the onset of sputum production The patient may be referred for an opinion as to the causation of an unexplained pyrexia in infants and children this is often so with multiple staphylococcal abscesses and pyrexia of unknown origin may be the first indication that a lung abscess is in fact present The sudden expectoration of a large quantity of pus is often the most helpful feature but as this may follow the intrabronchial rupture of an unsuspected empyema it is not diagnostic Once the active phase is over rapid development of clubbing of the fingers together with pain and swelling of the larger joints is not infrequent

Physical signs As in all chest disease the absence of obvious signs is not of diagnostic significance as the segment affected may be inaccessible to accurate percussion or auscultation A sign of value is the discovery of a tender area when the intercostal spaces overlying the abscess are palpated this tenderness is often fleeting being due to the over lying pleuritis which causes adhesions to develop with greater rapidity than in any other intrathoracic disease Diminished chest wall movements an increase of tactile fremitus and slight flatness to the percussion note may be detected followed by the presence of bron chial breathing over a strictly localized area When cavitation has developed amphoric breathing may be heard but this is not usual. Râles may be audible but are of little significance or help The greatest aid to diagnosis is the combination of obviously severe illness with pyrexia and chest pain that leads to the taking of radiographs of the chest

Sputum examination The sudden appearance of purulent sputum in a previously healthy patient is significant and its naked eye examination is most helpful Further examination includes a search for predominant organisms for elastic fibres (indicative of lung destruction) and for malignant cells in case the cause is a bronchial neoplasm

Radiology of lung abscess

Perhaps the commonest error is to expect a fluid level in lung abscess such levels are not seen in the early stages when the shadow cast has no more characteristic feature than consolidation or collapse of a broncho pulmonary segment (Fig 7 2) but even the discovery of this in patients with a history suggestive of lung abscess is important although other lung lesions may produce similar appearances

If the radiograph demonstrates a cavity with a fluid level it is still necessary to consider a tuberculous process a lung abscess due to neoplastic bronchial obstruction or an infected lung cyst

Differential radiological diagnosis

Radiological appearances vary enormously depending largely on the presence or absence of a fluid level When a solid infiltration is present the diagnosis from lung carcinoma suppurative pneumonia and tuberculosis may be impossible on radiological grounds and every help such as history sputum examination and bronchoscopy will be required In the middle-aged and elderly carcinoma of the lung is more often responsible for puzzling lung opacities than lung abscess and exploratory thoracotomy is often the final diagnostic resource if improvement with penicillin therapy is not satisfactory Exceptionally a lower accessory lobe may provide confusion

When a fluid level is present differentiation from empyema with broncho pleural fistula and from hydatid cyst disease as well as congenital accessory cyst is necessary in addition pulmonary neoplasm and pulmonary tuberculosis need to be excluded Lung abscess is usually a segmental lesion and the recognition of this fact helps greatly in differentiating from the empyema with a broncho pleural fistula The difficulty is chiefly seen when the empyema is of the interlobar type In empyema with a broncho pleural fistula the apex of the empyema cavity is usually triangular (see Fig 6 4)

In differentiating a lung abscess from a breaking-down peripheral carcinoma of the lung the latter has thick walls an extreme example of this is given in Fig 7 6

Tomography may help in showing a neoplastic obstruction in a bronchus leading to abscess cavity but this can be provided also by granulomatous tissue causing bronchiectasis lipiodol bronchography is of little value as the oil will not flow into the cavity except in a

chronic abscess of long duration lined by squamous epithelium As mentioned earlier bronchoscopy is of the greatest value in detecting or excluding bronchial tumours or foreign bodies



FIG 7 11 —A right lower accessory cyst in a woman of 32 with a long history of cough and sputum At operation the condition was typical of lower accessory cyst with an abnormal artery supplying it from the abdominal aorta

Treatment of lung abscess

The interventions required for lung abscess due to foreign bodies and those associated with neoplasm of the bronchus have been indicated (see pp 127–134)

As soon as a simple lung abscess has been diagnosed treatment by appropriate postural drainage and chemotherapy is instituted Two million units of penicillin or other appropriate antibiotic should be given daily and continued long after the general condition has improved, six weeks being an arbitrary period during which antibiotic therapy is required Sensitivity of the prevalent organism should be assessed constantly If the pyogenic organisms are penicillin insensitive, aureomycin or streptomycin in full doses is used, these are of especial value if Gram-negative organisms are considered to be responsible in part for the illness

With this regime few abscesses require external drainage and the change in outlook has been discussed previously If the patient has been diagnosed after the lapse of several weeks or has failed to respond to conservative measures treatment of the abscess by segmental resection or lobectomy is often indicated

Surgical drainage for lung abscess. *Quite exceptionally* a lung abscess is treated by simple open drainage which is reserved for seriously ill patients who are deteriorating under conservative measures and yet would probably fail to survive resection Because lung abscess is a peripheral lesion, which rapidly causes adherence of the visceral to the nearest area of parietal pleura, access to it through the bed of a resected rib is easy and safe unless it is in an unusual site adjacent to the diaphragm or mediastinum, although " peri-

pleural in the true sense of the word such abscesses are inaccessible and whenever possible should be treated by resection rather than by drainage In the more usual sites the abscess is adherent to the chest wall at a rib site that can be estimated accurately by a study of the radiographs in the postero-anterior lateral and oblique views

The operation This is performed under local anaesthesia after a meticulous radiological localization of the abscess and a portion of one occasionally two ribs resected sub periosteally If the incision has been made exactly over the site of the abscess a cautious incision through the periosteal bed will reveal pleural symphysis and the abscess can be opened immediately Two-stage drainage by which the evacuation of the abscess is delayed until adhesions have been produced by means of packing leaves a very ill patient still with unevacuated pus and hampered by a painful wound which inhibits the act of coughing when this method was in common use it was not unusual for the patient to die before the second stage could be completed If however the incision has been misplaced and the pleura is clearly free it must not be opened Two alternatives are possible either another rib is resected in the correct site or the wound is packed for a few days to produce a safer pleural adherence

Before the adherent lung is incised a large-bore needle mounted on a glass syringe containing a little sterile water is used to explore the abscess for the presence of pus or air obviously this should not be used until the rib has been resected as blind needling may be as dangerous here as in patients with subphrenic abscess (see Chapter 27) with every possibility of producing an empyema

The abscess cavity must be opened freely and all loculi thoroughly explored bleeding in the compressed oedematous lung tissue is slight When the cavity has been well opened it should be packed lightly with gauze which is replaced a few days later by a soft open drainage tube

SUPPURATIVE PNEUMONIA

(Suppurative pneumonitis)

The truth about pneumonitis however is that so many different people put a different content into the term that the very word breathes confusion and muddle (Coope 1946)

Every thoracic surgeon sees patients who are ill after a pyrexial lung illness followed by cough perhaps with haemoptysis and continued expectoration in whom the radiograph shows spreading areas of consolidation crossing from one lobe to the other with areas of cavitation The cavities are usually small the consolidation considerable and the clinical course is downhill with death some months after the onset of the illness The absence of tubercle bacilli led to the older description of non tuberculous consumption

Probably the diagnosis of suppurative pneumonia should not be made until the lobe or lung has been submitted to actual pathological examination either after excisional surgery or in the autopsy room or unless complete clinical resolution has followed for many patients so diagnosed in life have a bronchial obstruction usually due to carcinoma though occasionally to a foreign body but the condition undoubtedly exists Whereas lung abscess is typically a segmental disease suppurative pneumonitis keeps to no such rigid boundaries often spreading from segment to segment or lobe to lobe The main difficulty in the study of these pulmonary infections is that the evidence is largely radiological in patients who survive or who do not undergo surgical resections

"Pneumonitis" of surgical interest

As long ago as 1866 (Austin Flint), the word "pneumonitis" was employed as a generic term to include all examples of acute and chronic pneumonia, but this choice of terminology gained little favour. Acute lobar pneumonia and tuberculous disease are rigidly excluded from this group today. Radiologically an area of consolidated lung parenchyma in patients in whom the diagnosis of neoplasm, tuberculosis, lobar or virus pneumonia has been excluded as far as possible may be labelled as "pneumonitis" to differentiate it from atelectasis. The continued use of the term is only justifiable if it indicates uncertainty as to the true etiology and pathology of the condition. Most patients with "pneumonitis" have in fact bronchial carcinoma or lung abscess, but a small group, raised in incidence after epidemics of influenza, undoubtedly have a subacute, chronic or suppurative infection of the lung



FIG 7 12.—Radiograph of a woman of 52 who had suffered from cough, expectoration of purulent blood-stained sputum and pyrexia

The patient was referred to hospital as "unresolved pneumonia" At bronchoscopy a mutton bone embedded in granulation tissue was removed from the right lower lobe

parenchyma which persists, causes continued illness and is sometimes fatal. If the chests of sufficient people who have suffered from the common cold or influenza are radiographed, a reasonable proportion show opaque areas of considerable size in the lung parenchyma; the natural history of these opacities is that they disappear rapidly leaving no trace of their original presence, but in a few the areas enlarge and the clinical condition deteriorates. No specific organisms have been incriminated as the cause of this persistent lung infection; pathological examination after death or resection usually shows a condition that might well be described as a coalescing suppurative bronchopneumonia.

A particularly serious type of "pneumonitis" has been described by Sellors, Blair, Houghton, Thompson and Pryce (1946). They recorded 27 patients with a spreading inflammatory process in the lungs which invaded different areas of the lungs and usually cavitated; 10 died. The patients were ill and pyrexial with copious expectorations, occasionally foetid. The only satisfactory treatment of the patients who were studied over a long period to discriminate them from lung abscess, pulmonary tuberculosis or neoplasm

appeared to be excision which often involved pneumonectomy because of the widespread character of the disease These authors were not able to establish any definite etiology and called the state spreading suppurative pneumonitis The disease was noted chiefly in middle aged men

Persistent lung infection requiring surgery

A less dramatic but none the less serious group of patients are those with radiological appearances of pneumonitis that accompany general ill health with constant expectoration of purulent sputum often with haemoptysis In the middle-aged group although bronchoscopy fails to detect a tumour the assumption (usually a wise one) is that a carcinoma is present and thoracotomy reveals a chronically infected lobe which is resected

In younger patients chronic pyogenic infection of the lung not easily classified as lung abscess may persist in spite of all treatment and require surgical excision Such patients may start with a pyrexial illness the differential diagnosis being epituberculosis or pneumonia The expected resolution of these processes may fail to take place pyrexia persists and sputum production increases The condition is rare

A boy of 14 was admitted to hospital with the diagnosis of epituberculosis (see Fig 7 13) He had severe cough with little sputum and continued pyrexia (100–101) The Mantoux reaction was negative and remained so for the next 11 months during which period the amount of sputum steadily increased (up to four ounces a day) The result of persistent search for tubercle bacilli remained negative the sputum containing a mixed flora At bronchoscopy the right upper lobe was red and full of thick pus no caseating material was present and there was no evidence of bronchostenosis to support a diagnosis of atelectasis of the right upper lobe due to bronchial occlusion He was ill toxaemic and losing weight The right upper lobe was therefore resected and he made a complete recovery

The whole of the upper lobe was replaced by inflammatory tissue which contained multiple abscess cavities involving all segments The diagnosis of suppurative pneumonitis or pneumonia therefore seems acceptable

Nicholson (1950) has reviewed the subject of suppurative pneumonitis in considerable detail He applies the term suppurative pneumonitis to those patients in whom an inflammatory consolidation of the lung proceeds in part or in whole to suppuration Pneumococcal pneumonia does not proceed to suppuration in the way that infection with the staphylococcus or Friedlander s bacilli does If carcinoma is excluded as a cause of the suppurative pneumonia there is a residue of patients with non-specific chronic suppurative pneumonitis Their disease probably started as the result of aspiration of upper respiratory muco pus after such aspiration consolidation may develop which clears rapidly or the condition may persist as chronic suppurative pneumonia or proceed to further abscess formation

The chronic suppurative pneumonia group may develop abscess cavities that come and go These patients may respond to treatment with penicillin and sulphamethazine but if chronic structural changes such as bronchiectasis or cavities persist the condition is dangerous in addition to being a cause of continuing chronic ill health The best hope of recovery lies in resection of the diseased lobe or lung The surgeon therefore who resects a lobe or lung with chronic suppurative pneumonia as occasionally happens when he thinks he is removing a carcinoma often saves the patient from chronic ill health or death Chronic suppurative pneumonia is a serious disease and is fundamentally a surgical problem Before surgery is undertaken a complete clinical survey including bronchoscopy must be completed the commonest errors being to classify a patient as suffering from pneumonitis when the condition is due to tuberculosis bronchial carcinoma or foreign body obstruction

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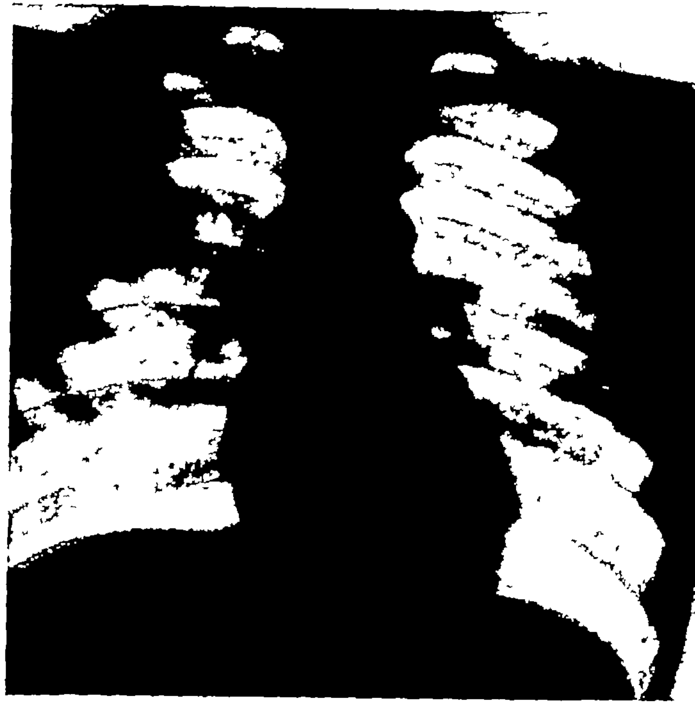
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(a)



(b)



(c)

FIG 7 13

(a) Radiograph of a boy of 14 years the condition was regarded at first as epituberculosis, but the Mantoux reaction was negative

(b) Eleven months after radiograph shown in Fig 7 13 (a)
A P view Obvious progression of the inflammatory process

(c) Lateral view of chest Mantoux still negative
"Suppurative pneumonia" See text

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A honeycombed upper lobe in adults used frequently to be labelled as "congenital cystic disease", undoubtedly infants have been born with honeycomb lungs in which the evidence favours a congenital origin, but most of the adult patients previously regarded as having congenital cystic disease were examples of acquired saccular bronchiectasis, due to upper lobe stenosis, the result of compression by enlarged tuberculous glands or actual bronchial disease Figs 8 2 (*a*) and (*b*) represent such a type, the soap-bubble appearance on the straight radiograph and the confirmatory bronchogram are not evidence of congenital



(*a*) (*b*)

Fig 8 2

(*a*) Radiograph of a woman of 30 complaining chiefly of haemoptysis
The soap bubble appearance of the right upper lobe is characteristic of what previously was called "congenital cystic disease"

(*b*) Bronchogram of the same patient
Upper lobectomy revealed partial upper lobe stenosis due to old healed tuberculous glands

origin, the lobectomy specimen from this patient had the features of acquired saccular bronchiectasis due to a compressed right upper lobe bronchus, the result of healed tuberculous glands.

In another patient a left lower lobectomy was followed by an abscess around the bronchial stump Over the course of several months the left upper lobe became cystic on the radiograph and sputum production increased, a residual lobectomy was performed

Congenital malformations such as solitary cysts or dissociated lobes or reduplications of the foregut (see p 23) are not infrequently complicated by bronchiectasis in the surrounding lung tissue, possibly as a result of infection in the misplaced tissue or from pressure on neighbouring air tubes into which fistulae may form

The bronchiectasis of the upper lobe above the "dissociated" lobe, illustrated in Fig 8·4, was undoubtedly acquired as a complication of the associated congenital defect

The present tendency is to regard most examples of bronchiectasis as being acquired and only a few cases of congenital cystic disease can be accepted with confidence In the

radiological diagnosis of circular spaces in the lung perhaps the term honeycomb lung is more satisfactory than that of cystic disease Such appearances may be caused by acquired bronchiectasis true congenital cystic disease or emphysematous disease



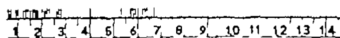




Fig 8·3 Fig 8·4

Fig 8 3.—This left upper lobe provided a radiograph with bubble appearance of cystic disease

A left lower lobectomy had been followed by small empyema around the bronchus stump either as a result of bronchial embolism from this abscess or because of upper lobe stenosis due to the enlarged glands which are seen in the photograph the left upper lobe became cystic Lobectomy specimen showing acquired saccular bronchiectasis. The probe is in the stump of the lower lobe bronchus.

Fig 8 4 —A large lower lobe cyst complicated by upper lobe saccular bronchiectasis.

During the pneumonectomy an abnormal systemic artery derived from the abdominal aorta was seen entering the area of the cyst of the lower lobe which is congenital in origin.

The Kartagener complex

In 1933 Kartagener described a group of patients with bronchiectasis who had transposition of the viscera detected by discovery of dextro-cardia associated with congenital abnormalities of the para nasal sinuses notably absence of the frontal ones Just under half of these patients have symptoms of cough in the first ten years of life and a quarter develop them in the next decade Adams and Churchill (1937) pointed out that the bronchiectasis in this type of patient had the characteristics of the acquired condition and later Churchill (1940) was able to report two patients with only two features of the trilogy (dextro-cardia and absent accessory nasal sinuses) who had no bronchiectasis He described the moist exaggerated bronchial secretions of these patients who were carefully treated with chemotherapy when respiratory infections developed and he hoped that this careful management might prevent the development of bronchiectasis which is probably

acquired secondarily in the so-called Kartagener syndrome and is not truly a congenital lung condition

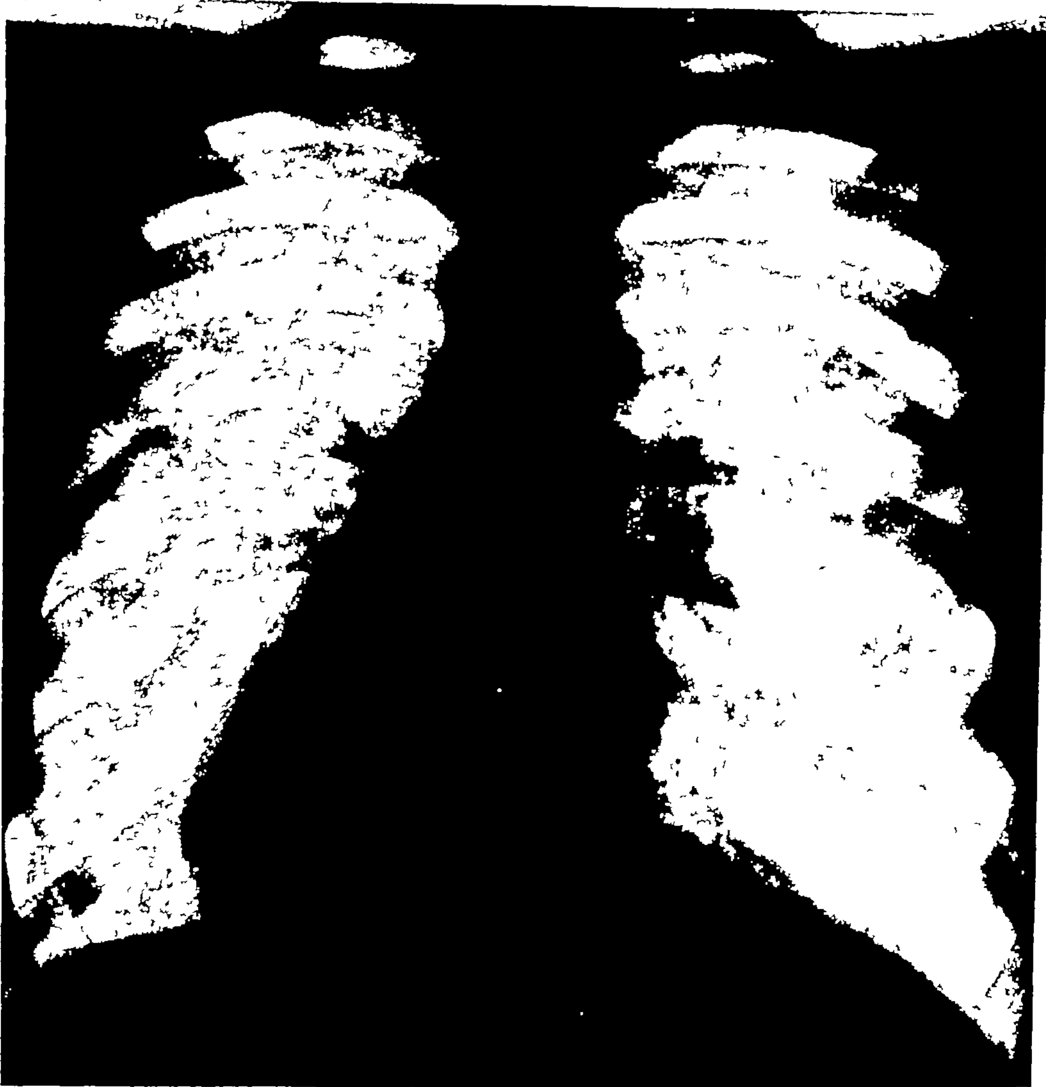


Fig 8 5 —The Kartagener complex
A boy of 8 with dextro cardia the seventh right and the sixth left rib have regenerated after excision The left middle lobe and the right lingula have been resected for bronchiectasis

The mechanism of acquired bronchiectasis

The common etiological factors are probably bronchial occlusion and the continued presence of infection in the bronchial wall itself If the affected bronchus is occ b body material or intrabronchial plugs of tenacious muco-pus which are or removed, or if the bronchial wall itself is stenosed as in broncho-ste tuberculous granulation tissue or neoplastic tissue or by the pressure lesions such as glandular hypertrophy, pyogenic or tuberculous, fully ectasis may ensue Beyond such blocking agents the air within the a segment becomes absorbed and the alveolar walls adhere to each other of the nature of their cartilaginous wall, do not collapse but per atmospheric pressure encourages their dilatation especially if w

rapidly as can be seen when a lobe collapses massively after an abdominal operation when pyrexia and severe malaise develop almost immediately

The commonest occluding mechanism is probably provided by enlarged peri bronchial lymphatic glands or the lodging in the bronchi of thick muco pus This latter mechanism is probably the explanation of those common examples of bronchiectasis that develop in children after they have suffered from the evil combination of measles and whooping cough But bronchiectasis is seen after foreign bodies have been left because of their unsuspected presence and in lobes or lungs rendered airless by obstruction due to growth





(*a*) (*b*)

FIG 8·6 —Bronchiectasis beyond an adenoma of the right lower lobe bronchus The histological appearances of the tumour are shown (Dr A. Brian Taylor's case)

Many examples of bronchiectasis have their origin in tuberculous disease *in children* this may be due to compression of the bronchus by enlarged tuberculous glands or by actual tuberculous endo bronchitis The best example of this etiology is provided by the middle lobe syndrome in this common combination the middle lobe collapses and a *careful* study of the radiograph often shows a tuberculous complex in the right lower lobe Not all of these lobes re-expand and if the obstruction persists bronchiectasis is inevitable and may not cause symptoms until adult or middle age

Roberts and Blair (1950) have presented *interesting* and convincing views of the etio logical factors of bronchiectasis following tuberculosis in children Of 400 examples of primary lung tuberculosis 77 (19 per cent) *had* later collapse of a lobe segment or lung 37 of these were subjected to bronchography and bronchiectasis (often symptomless) was found in 34 In several of these patients *during bronchoscopy under general anaesthesia* the intrapleural pressures were measured and showed no increase in the negative intrapleural pressure Roberts and Blair believe that the bronchi dilate under the increased intra

bronchial pressure provided by distension, the result of retained mucus, caseous material or secondary infection of the retained mucus beyond the site of the bronchial obstruction The important application of their finding is that a Mantoux test should be made in all children with collapse of the lung or bronchiectasis and surgical excision if recommended should be delayed for two years, streptomycin being given to cover the operative procedure if a tuberculous etiology is proved or suspected At the Children's Hospital, Birmingham,



FIG 8 7—*A typical example of middle lobe obstruction due to tuberculous glands, no lipiodol has entered the middle lobe*

The lobe failed to re-expand after a year's conservative waiting because of constant cough and occasional haemoptysis the lobe was removed with uneventful convalescence gross bronchiectasis was present in the middle lobe, the bronchus of which was occluded by healed tuberculous glands

lobectomy is delayed for a year in all children with a positive Mantoux reaction There have been no examples of tuberculous complication following resections in patients so managed.

There is a good deal of evidence (Negus) that bronchial obstruction hampers the beneficial effects of the ciliary action of the bronchial mucous membrane below the site of the obstruction and the loss of this function prevents the removal of bacteria from the bronchus affected and infection rapidly develops

Bronchiectasis associated with para-nasal sinus infection

As many patients with bronchiectasis have para-nasal sinus infection it is important to consider the implication of this combination It is clear that major rhinological operations almost invariably fail to improve the state of the upper respiratory passages in the presence of bronchiectasis and yet notable improvement may follow successful resections of the diseased lung area The constant bouts of coughing may infect the nasal sinuses and induce or aggravate the state of sinusitis Riggins (1941) has considered this point

arefully in 100 cases of bronchiectasis 30 had chronic sinus disease and 20 of these had een known to have had bronchiectasis from several months to several years before they eveloped the nasal disease He indicated also that most patients with bronchiectasis had hat disease in their first decade of life whereas the association of para nasal sinus disease vith the lung condition developed most frequently in the second decade of life These gures suggest that sinus infection may be secondary to or aggravated by the bronchiectasis

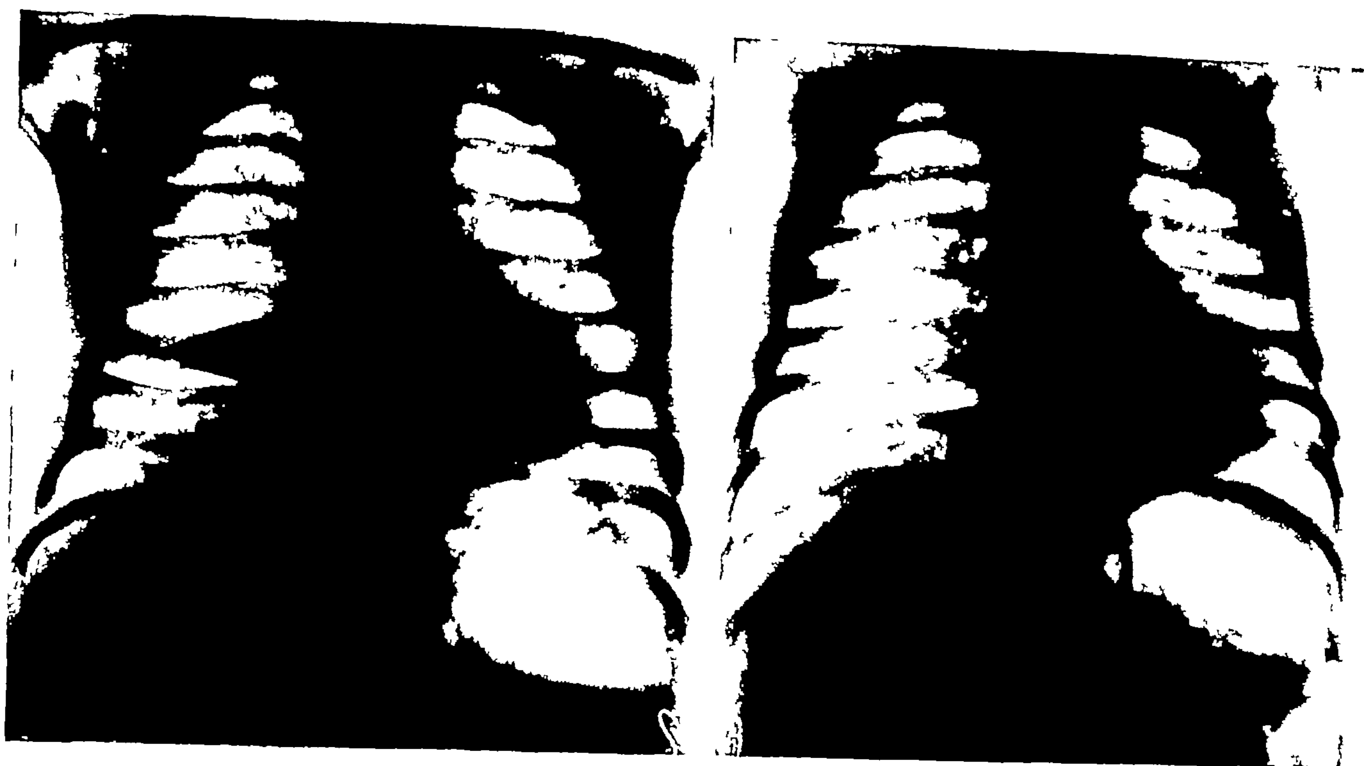
Brock (1950) favours the postponement of major nasal operations until after the lung as been operated upon when surgery for bronchiectasis is indicated.

This simplified version describing collapse and infection as the main etiological factors n bronchiectasis fails to explain the peculiar distribution of the disease in so many patients ung abscess is due to bronchial embolism of infected material in most instances and affects hose areas of the bronchial tree most vulnerable to aspiration from above namely the posterior segments of the right upper lobe and the apical segment of the right lower lobe In bronchiectasis however the lower lobe and the lingula of the left side and the middle lobe of the right lung are the areas commonly involved If bronchial embolisms alone were the cause of bronchiectasis the right lower lobe would be affected more often than the left The obliquity of the left bronchus may be responsible for difficulty in expectorating pent up secretions in the lower part of the lung

Bronchial obstruction however explains the development of the condition in such diverse pathological states as retained foreign bodies the inhalation of infected material from the upper respiratory passages as a complication of tuberculous disease whether of the bronchial wall or of the adjacent lung lymphatic glands and in patients with carcinoma or adenoma of a bronchus

Bronchial infection as a cause of bronchiectasis

In the British literature it is possible that the rôle of lobar or segmental collapse has been exaggerated as a cause of bronchiectasis and the part played by infection under-estimated. Especially after bronchopneumonia not only the mucosa of the bronchi are infected but also wide areas of lung parenchyma If the infections are repeated the bronchi become damaged with loss of mucosa and of elastic tissue This combined with deficient expansions of damaged areas of the parenchyma which decrease aeration may well lead to dilatation of the bronchi especially when these are subjected to continued stress from repeated bouts of coughing after measles and whooping cough cylindrical and saccular bronchiectasis can then follow The process may be accentuated and accelerated by the secondary derangement of obliterative bronchitis and by the presence of enlarged lymphatic glands in the hila of the lobes secondary to the septic process in the lung and bronchial tissue The resultant areas of collapse may involve the whole lung a whole lobe or isolated segments and explain the mixed pattern of bronchiectasis so often seen especially in children whose soft walled bronchi are more vulnerable to obstruction by enlarged glands pyogenic or tuberculous A common example of this is noted in the frequency of middle lobe collapse in children after respiratory infections this is due no doubt to the actual arrangement of lymph glands around the middle lobe bronchus which is specially vulnerable to glandular compression as emphasized by Brock. Although middle lobe collapse may often clear this by no means always happens and in a series of 171 lobectomies or segmental resections (see p 160) 20 middle lobes were the seat of irreversible bronchiectasis and required removal Middle lobe atelectasis may persist for six months to a year before bronchiectasis develops If re-expansion has not occurred after a year the outlook is not good without operation as persistent cough of an asthmatic type and small haemoptyses are common Once



(a) (b)

Fig 8 8

(a) Collapse of the right middle lobe in an infant
(b) Re-expansion of the middle lobe fourteen days later



(a) (b)

Fig 8 9

(a) Bronchiectasis of the right middle lobe in a boy of 9 years
At this time there was also bronchiectasis of the left lower lobe and lingula, which were resected
(b) Bronchogram a year later
There is still gross bronchiectasis of the right middle lobe, but its upper segment has apparently improved
The middle lobe was resected

bronchiectasis has developed it is almost invariably irreversible though partial re-aeration and decrease of the bronchial dilatation is possible

Fibrocystic disease of the pancreas and bronchiectasis

The association of lung infections with cystic disease of the pancreas is well recognized In these patients with gross nutritional deficiencies bronchopneumonia atelectasis bronchiectasis and emphysema are common and usually fatal Once emphysema has developed death is usual but if the lung complications are treated early by antibiotic therapy and the

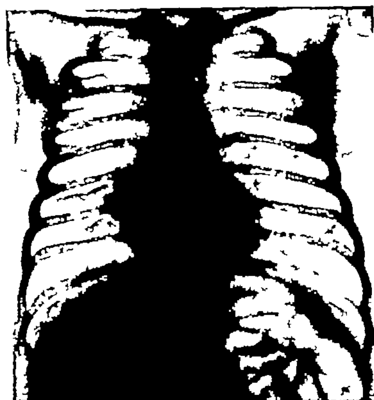


FIG 8 10—Atelectasis (right upper lobe and middle lobe) and emphysema of the left lung with depression of the left diaphragm and widening of the intercostal spaces in a patient with fibrocystic disease of the pancreas.

nutritional condition improved, occasionally recovery is possible Andersen (1949) thinks the origin of the lung pathology may be due to a specific nutritional deficiency The further investigations of this condition may throw light on the pathogenesis of bronchiectasis

Reversible bronchiectasis (pseudo-bronchiectasis)

After collapse of a lobe or after respiratory infections the bronchi may show a dilatation demonstrable by lipiodol bronchography With improvement in bronchial drainage re-expansion of the collapse and a restoration to normal of the inflamed bronchial mucosa this dilatation can undoubtedly disappear (Jennings 1937) This has been proved in a considerable number of patients by follow up bronchography The difficult point to establish is how long a lobe or segment may remain collapsed with dilated bronchi before the process becomes irreversible I know of one child with proved bronchiectasis in whom the condition disappeared after a year s wait this result was confirmed by bronchography It is however unusual but at least six months can be spent profitably in waiting for this

agreeable sequel if the child can be treated by fresh air, breathing exercises and chemotherapy in cylindrical bronchiectasis resolution does not happen in saccular bronchiectasis

Pathology

The bronchi may dilate into cylindrical dilatation or into clearly defined saccules.

The macroscopic appearances of the lobe in bronchiectasis depend largely on the degree of atelectasis present If this is extreme the lobe is solid and contains a mass of dilated bronchi, closely approximated The parenchyma is solid and often shows patches of pneumonic consolidation with extensive areas of fibrous tissue and the whole lobe is

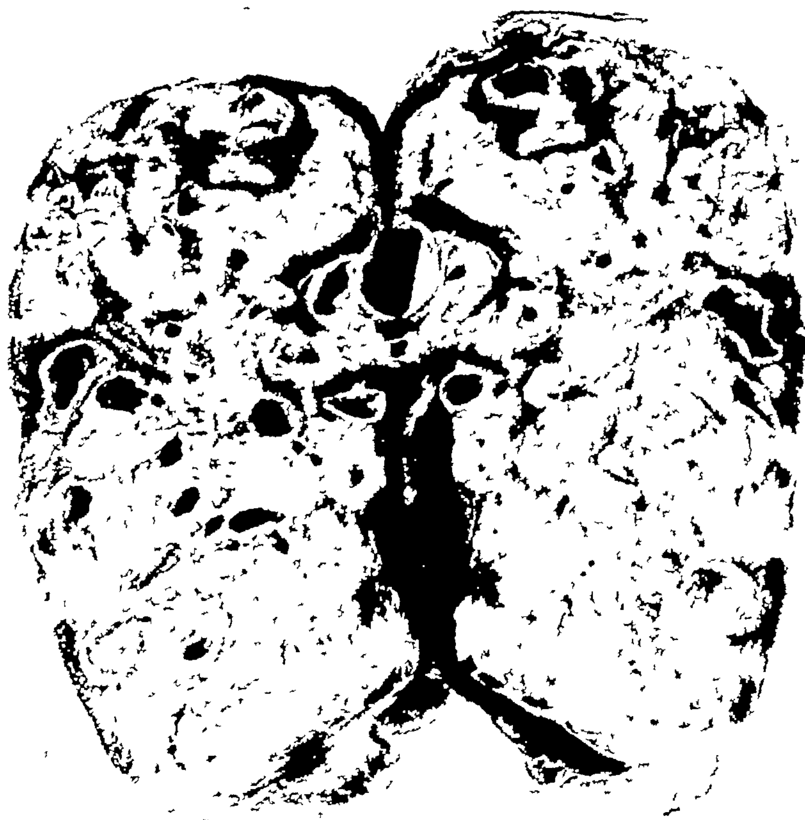


FIG 8 11 —Gross bronchiectasis of the left lung Pneumonectomy specimen (width 16 cm)

shrunken The bronchi are dilated and may retain a reasonably good pattern or be distended into saccular spaces the mucous membrane is often swollen with ulceration in parts (Fig 8 12 (*b*)) , the elastic fibres of the bronchus are hypertrophied in areas, and fragmented in others Microscopically the ciliated bronchial mucous membrane often changes to cuboidal or flattened epithelium the spread of infection beyond the bronchial wall may produce areas of fibrosis, pneumonitis, obliteration of vessels (Fig 8 12 (*b*)),* or true suppurative foci may be present Pleural adhesions may be dense and are evidence that the disease

* The obliteration of vessels is interesting In non-tuberculous bronchiectasis the larger vessels remain intact, as demonstrated by post-lobectomy infusion with radio-opaque solutions , in tuberculous disease that has destroyed the lobe or caused its collapse the reverse is the case These vascular effects probably explain why in bronchiectasis there may be a decrease in arterial oxygen saturation which is abolished after resection in fibrocaseous tuberculosis there is rarely a decrease in arterial oxygen saturation The inference is that in bronchiectasis there is a venous arterial shunt mechanism (Gobbel, Gordon, Digman and Brook, 1951)

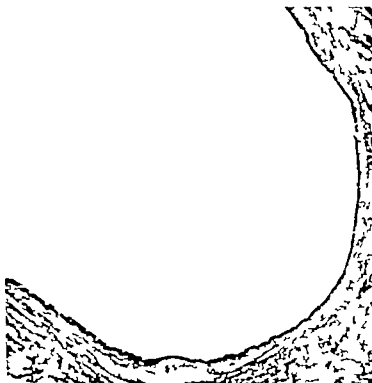




(a) (b)

Fig 8-12

(a) Acquired bronchiectasis showing purulent exudate in the dilated bronchus and ulceration of the bronchial wall. (Dr H. Baar)
(b) Acquired bronchiectasis showing infiltrative mural bronchitis, disintegration of elastic fibres replacement of parenchyma by granulation tissue and obliterating endarteritis. (Dr H Baar)



(c)

Fig. 8 1_

(c) Congenital bronchiectasis showing cystic spaces lined by cuboidal epithelium and no inflammatory changes of the wall of the cysts. (Dr H Baar)

has caused pleurisy, but quite frequently severe bronchiectasis may be present without any significant adhesions

Many lobectomy specimens removed from patients with copious sputum show an apparently healthy parenchyma and at operation the lobe may have appeared quite normal Frequently there is an obvious lack of carbon pigment, evidence of a lack of full alveolar ventilation Sometimes bronchiectasis may show little or no gross radiological changes on the plain X-ray film, apart from translucency due to associated emphysema (Fig 8 13), the diagnosis being made on a bronchogram taken for the investigation of a patient with continuous expectoration of purulent sputum More usually, however, a collapsed lower lobe is seen behind the cardiac shadow or more clearly on the right side

Changes produced in the mediastinum, the lymphatic glands and the unaffected lobes of the lung

Gross alteration may develop in the position of the mediastinum, the character of the lymphatic glands and in the remaining parts of the lungs These depend largely on the degree of atelectasis and of infection Total atelectasis of one lung will lead to a marked swing over of the mediastinum to the diseased side and a considerable displacement is seen if only one lobe is completely collapsed Compensatory emphysema is often notable and its presence on one side of a chest radiograph may be the clue to the detection of a collapsed lower lobe, especially when the left lower lobe is contracted into its typical triangular shape behind the cardiac shadow

The lymphatic glands and the hilar structures may be greatly enlarged and much matted as the sequel to the infection in the bronchiectatic area These changes may provide difficulties in the surgical dissection necessary in an excisional operation

Distribution of bronchiectasis

Bronchiectasis tends to involve segments rather than lobes, the basal segments of the lower lobes being more commonly affected than those of the upper ones The lingula segments on the left and the middle lobe area on the right are, however, frequently involved, which is quite different from the incidence of tuberculosis or lung abscess which tend to attack the more posteriorly placed broncho-pulmonary segments, the apical segment of the lower lobe (dorsal lobe) is often spared from disease when bronchiectasis is involving the remaining segments of the lower lobe Acquired bronchiectasis is unusual in the upper lobes though honeycomb appearances are not uncommon, probably representing acquired disease secondary to bronchostenosis from healed tuberculous glands around the upper lobe bronchus

Bronchiectasis is often bilateral (30 to 40 per cent) and when this is so the pattern of disease on one side is often curiously mirrored on the other For example, the combination of bronchiectasis affecting both lower lobes and the lingula on the left and the middle lobe on the right is a common one. Equally striking is the picture presented in the rather unusual event of the disease attacking the anterior segments of both lungs, if the disease is bilateral and the dilatations are present in the anterior basic segment, the middle lobe segments and the pectoral segment of the right upper lobe, the corresponding areas of the left lung will usually show these anatomical changes

Bronchiectasis may affect one lobe only, the left lower lobe being the one most commonly involved (41 of 190 patients—see Table II), or it may involve segments in all lobes on one side with the other side quite unaffected But even in these types of distribution it is unusual to find all segments of a lobe or of a lung involved though the treatment indicated may

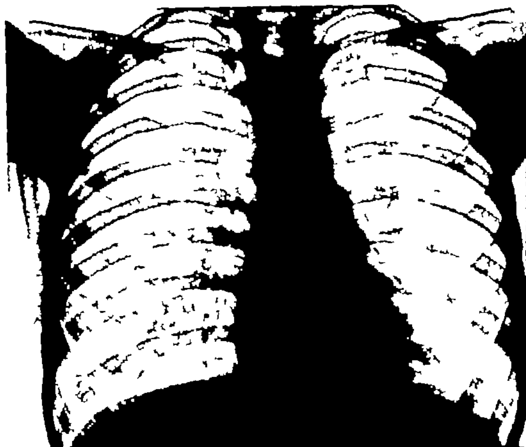


Fig. 8.13 (a).—Radiograph showing translucency of left lung field in a child with cough and sputum. Because of the emphysema of the upper lobe a bronchogram was done (Fig. 8.13 (b)).

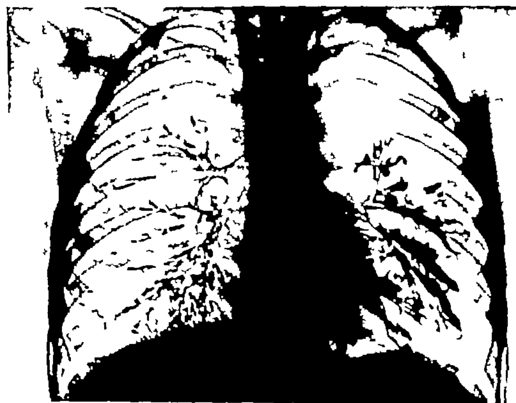


Fig. 8.13 (b).—Bronchogram showing extensive cylindrical bronchiectasis in left lung



FIG 8 14.—Bronchogram showing fusiform bronchiectasis in a collapsed left lower lobe lying behind the heart



FIG 8 15 —Atelectasis right lower lobe

Mediastinal displacement to the right and increased translucency of right upper lobe due to emphysema

demand total lobectomy or total pneumonectomy In about 8 per cent of cases the disease affects segments of all lobes in one lung

TABLE II

DISTRIBUTION OF BRONCHIECTASIS IN 100 OPERATED PATIENTS
(1947–1950—4 years)

A L d Abreu and R H Brain

210 operations
20 bilateral resections
39 pneumonectomies (of which 5 were residual lobectomies the upper lobe being resected because of its persistent collapse after lower lobe resection)

The Distribution of Disease in 171 Lobectomies or Segmental Resections

Left lower lobe and lingula	60
Left lower lobe	41
Right lower and right middle lobe	24
Right middle lobe	20
Right lower lobe	6
Lingula	4
Right upper lobe	1
Segmental resections	15

Of these 10 were accepted as congenital because of the presence of an abnormal artery derived from the systemic circulation 8 of these accessory cystic lobes (dissociated cysts) were attached to the left lower lobe 2 to the right lower lobe

TABLE III

INCIDENCE OF BILATERAL DISEASE IN PATIENTS WITH BRONCHIECTASIS ACCEPTED FOR SURGERY

	Patients
Total number with bilateral disease	50
Subjected to unilateral excisions	30
Subjected to bilateral excisions	20 (i e 40 operations)

These figures based on operation subjects only are no indication of the true distribution as it is presumed that patients with bronchiectasis who are referred as surgical risks do not have the most extensive involvements but they do serve as an indication of the high incidence of bilateral disease and of the frequency with which the left lower lobe and lingula are affected

Holmes Sellors has listed the distribution in a recent series as follows (Table IV)

TABLE IV

DISTRIBUTION OF BRONCHIECTASIS IN 100 CONSECUTIVE LOBECTOMIES

Left lower lobe and lingula	35
Left lower lobe only	30
Right middle and lower lobes	15
Right lower lobe only	9
Right middle lobe only	7
Right upper lobe	2
Left upper lobe	2

In the same period there were 15 pneumonectomies for involvement of all lobes on one side and 4 bilateral lobectomies (*Holmes Sellors*, 1950)

Overholt and Langer (1949) in 100 consecutive patients with bronchiectasis found that 85 per cent had multiple segments involved and that in 30 per cent the disease was bilateral.

Clinical features of bronchiectasis

Persistent cough with the production of purulent sputum are the common features, but in young children the sputum is frequently swallowed and the parents' story of lack of sputum must not be accepted readily, nor can reliance be placed upon the amount of daily sputum as stated by most patients, and after the institution of satisfactory postural drainage in hospital this amount is often twice as much as that described In most instances the greatest quantity of sputum is expelled by the patient after he wakes in the morning

Frequently the sufferer sleeps on the most affected side, to prevent sputum from draining into the upper healthy tracheobronchial tree where its arrival will initiate the cough reflex

Haemoptysis is not usually severe and is commoner in adults than children although saccular disease is less common than the more usual cylindrical type of bronchiectasis, haemorrhage is more frequent in that group Haemoptysis without the expectoration of purulent sputum is often reported it used to be referred to as "dry bronchiectasis", but when these patients are in hospital the adoption of active postural drainage movements invariably discloses the presence of true sputum The bleeding arises from the bronchial vessels

One of the notable changes in this disease is the disappearance of the patients who used to present themselves as social outcasts, because of their offensive sputum, the first five patients on whom I operated in 1935 all had this offensive sputum but it is now rare, partly because the patients with chronic cough are investigated before advanced changes have taken place in the affected lung or lungs, but chiefly from a change in the bacterial flora (see p 129) Similarly it is unusual to see patients with advanced toxaemia and amyloid disease, though less degrees of chronic ill-health are common Most of the children seen are much below their weight and height and normal development often follows successful lobectomy, fatigue and frequent pyrexial illnesses after colds are common features the important history of repeated "pneumonia" often indicates recurrent infections in atelectatic lobes giving rise to pyrexia, dyspnoea, increase in cough and physical signs over the affected area

Clubbing of the fingers is common but may be absent even in severe degrees of infected bronchiectasis

The physical signs in the chest may be surprisingly minimal, sometimes absent, when signs are present most reliance will be placed on poor chest wall movement over the affected area, slight dullness on percussion and the presence of moist râles If the affected lobe is atelectatic bronchial breath sounds may be audible, but even when the radiograph shows undeniable evidence of a triangular collapsed lower lobe the stethoscope may fail to detect bronchial breathing if the bronchus at that moment is blocked by intrabronchial contents or because of complete occlusion, the result of extrabronchial compression from enlarged lymph glands

The diagnosis will be made in most patients if the history of a persistent cough, often with associated finger clubbing, leads to a complete radiological examination

Radiological appearances

The whole plan of treatment will depend upon the radiological findings Before the patient is submitted to surgery a full account must be available of the state of every bronchopulmonary segment of both lungs and this can only be obtained after lipiodol bronchography.

The preliminary plain radiograph The appearances vary from negligible changes of increased shadows beyond the normal ones cast by the pulmonary vessels to the gross appearances of total lung or lobe atelectasis associated with considerable displacement of the trachea mediastinum and heart to the side of the airless lung and with compensatory emphysema of the other lung or of the lobe not affected by atelectasis Atelectasis is most often shown as a triangular dense shadow and this will be accompanied by translucency of the emphysematous left upper lobe (see Figs 8 13(*a*) and (*b*)) In saccular bronchiectasis or in cystic disease of the lung the cysts may be shown quite clearly (Fig 8 10)



Fig 8 10.—Gross saccular bronchiectasis in a woman of 45 years.

Bronchography

The performance of this is in every respect as important as the resection operation prognosis and treatment depending upon accurate bronchograms fully studied and noted To attain really good bronchograms the patient should have undergone a preliminary course of postural drainage the presence of thick sputum not only interferes with the adherence of thick viscous iodized oil to the walls of the bronchi but is often the cause of severe coughing during the operation which will ruin the bronchographic appearances

Methods There are several ways of producing a satisfactory filling of the bronchi Except in children one side should be filled so that accurate lateral views can be obtained without the confusion of overlapping shadows being cast by the presence of oil in the other lung But good bronchograms can be obtained by bilateral filling if oblique films are taken

The oil may be introduced by

(1) an intranasal catheter or a thin tube passed through an intratracheal tube
(2) dropping lipiodol over the back of the tongue into a cocained larynx
(3) a puncture through the crico-thyroid membrane

(a) (b)

Fig 8·17—Bronchogram in an adult, both sides filled at the same time

The study of the postero-anterior and oblique radiographs indicates "cystic bronchiectasis" of right lower lobe, a bronchiectatic accessory right tracheal lobe and a normal left lung in all segments



Fig 8·18—Saccular or cystic bronchiectasis involving all lobes of the right lung in a child of 4 years with copious sputum

The oblique view of the left lung shows that side to be free from disease Uneventful pneumonectomy

In all methods success will depend upon securing the co-operation of the patient and the radiological staff: the pictures must be made in the X ray room to avoid all delays (during which even the best patient may cough) and to prevent the iodized oil passing too far into the alveoli and so producing a blurred indeterminate picture. The viscous oil should not be warmed because this makes it too liquid, which encourages alveolar filling instead of delineation of the bronchial wall. Adherence of the oil and avoidance of alveolar filling is increased by adding 4 to 5 grammes of sulphanilamide powder to each ampoule of lipiodol. The crico thyroid puncture method is not recommended; it is uncomfortable and has possible risks not associated with the other methods.

Bronchography in children. I am indebted to Dr Roy Astley and the late Dr Helen Wood for this short account of their method.

The child is admitted to the ward the previous day for postural drainage and breathing exercises. The following morning the child is given rectal avertin 0.1 c.c. per kilo body weight and atropine gr $\frac{1}{100}$ (0.6 mgm.) twenty minutes before leaving the ward.

In the X ray Department anaesthetization is started with nitrous oxide oxygen ether by Boyle's semi-closed method. When the jaw is relaxed the largest possible oral portex endotracheal tube is introduced under direct vision so that the tip lies just above the carina. As soon as the tube is in place the child's tracheo-bronchial tree is sucked out; if the sputum is copious the foot of the couch is raised and the child turned first on one side and then on the other. When anaesthesia is at the lower level of the third plane of the third stage (Gudal) the patient is raised to a sitting position and lipiodol introduced into the trachea through a narrow rubber tube attached to a record syringe. The length of this tube is always measured to correspond with the endotracheal tube and is inserted inside the endotracheal tube; each breath is noted and if the child is small and there are signs of obstruction the inner tube is withdrawn immediately.

The child is then supported in the sitting position slightly inclined towards the side for bronchogram and just over half the total dose of lipiodol is injected. After a short pause the child is tilted over to 45° from the straight and a quarter of the remaining lipiodol is run in. The patient is then inclined forward to 30° and the remaining lipiodol given. The child is then lowered sideways till the head is level with the couch and after a minute is carried into the X ray room, the side with the lipiodol being kept underneath and the head maintained in a low position; this aids the filling of the upper lobe and prevents any lipiodol passing to the other side.

Radiographs are taken quickly in the lateral, the oblique and the anteroposterior positions.

On return to the outer room the excess lipiodol is removed by suction, the anaesthesia deepened and the technique repeated on the opposite side to enable films to be taken in the oblique and anteroposterior positions. The tracheo-bronchial tree is sucked clear and the child returned to the ward.

The sucker must be small in relation to the endotracheal tube to avoid producing too high a negative pressure in the bronchi.

By this method

(1) right and left bronchograms can be obtained at the same session;

(2) the child is not frightened and will return willingly for further treatment;

(3) there is no element of obstruction so that the child's colour is good throughout the whole proceeding;

(4) excess lipiodol is removed, so that little is shown in the alveoli at subsequent radiographic examinations.

The chief difficulty of bronchography in children is excessive sputum; if this is removed before the instillation of the lipiodol the tendency to over-fill the bronchi and to spill over into the other lung is avoided.

The treatment of bronchiectasis

The problem under discussion relates to bronchiectasis produced other than by bronchial neoplasm, pulmonary tuberculosis, lung abscess or foreign body, though frequently treatment in that group calls for lung, lobe or segment resection.

Many patients with bronchiectasis will die of the disease unless complete surgical removal can be achieved, and it is important to remember that this is often a fatal disease, though less rapidly so now than in former days. The patients rarely reach their expected span of life, many of them not treated surgically dying in the fourth or fifth decades; the prognosis is much worse in lower lobe bronchiectasis than in disease of the upper lobes. Riggins (1941) believes that few patients developing the disease in the first decade live to be forty and quotes figures from other authors which showed a high mortality rate in those not treated surgically. The often quoted opinions of Jex-Blake, that the expectation of life after diagnosis in the medically treated patients was only five years, would certainly be regarded as unduly pessimistic at present when amelioration by postural drainage, chemotherapy and antibiotics is available. The melancholy after history of patients with bronchiectasis should be borne in mind when the treatment of the disease in children is being considered, and the clinical condition of many patients in the late twenties and thirties who produce daily large quantities of sputum and exhibit the breathlessness and cyanosis of advanced pulmonary heart disease is a pathetic one.

Bronchiectasis is as serious as many types of pulmonary tuberculosis; the least serious type being that of cystic character affecting the upper lobes. In the usual forms of bronchiectasis, apart from the chronic ill-health so often present, the dangers to life are from metastatic brain abscess, lung abscess, foetid empyema, toxaemia and right-sided heart failure; occasionally death may follow from fatal haemorrhage.

Quite apart from the mortality risks of bronchiectasis the distressing constant expectoration of sputum, sometimes offensive, the recurrent haemoptysis, the repeated "pneumonia" and the gradual decrease in respiratory efficiency indicate resection as the treatment of choice whenever it is possible and when adequate bronchography indicates that complete removal of the bronchiectatic areas is possible. Operation is not advisable in the elderly, the eldest in my series being 61; it is contra-indicated if the resections involved would lead to the sacrifice of so much lung tissue that a reasonable respiratory function would be unlikely; it must be said at once, however, that many patients who have undergone resection of both lower lobes and of the lingula and middle lobe are free from dyspnoea and have excellent respiratory function. Bilateral disease is certainly no longer a contra-indication to successful surgery and the establishment of safe techniques for segmental resection have widened the scope of surgery.

The morbidity is grave: many of the children with bronchiectasis have suffered greatly from loss of school hours, spending many days in bed at home or in hospital during exacerbation and recurrent attacks of pneumonia. Although established bronchiectasis rarely spreads to other lobes, as is commonly believed,* the previously healthy lung tissue is sub-

* Dr R. Astley at the Children's Hospital, Birmingham, has repeated many bronchograms in patients with inoperable bronchiectasis and in only one has found bronchiectasis developing in another lobe, though progression of the bronchiectasis in the affected lobes has been noted in many.

jected to repeated attacks of infection and is grossly damaged by an increase in compensatory emphysema which passes on to the pathological state and is the cause sometimes, of right sided heart failure The constant coughing from an infected collapsed lobe often increases the extent of emphysema in the already over-distended associated lobes which may be further affected by the development of obliterative bronchitis the result of frequent re infection The social and economic disabilities of the patient with bronchiectasis are generally severe

Amyloid disease (rare unless associated with tuberculosis) is no longer a contra indication to resection and in fact its early diagnosis in a patient with bronchiectasis is an indication for resection if the case is operable for it is not irreversible in its early stages

Palliative treatment Some patients because of delay in reference to surgical treatment or because of the extensive involvement of both lungs beyond the limits of possible segmental resection are quite unfit for excision. They can be improved by active postural drainage breathing exercises and the use of penicillin inhalations A period in hospital under the active supervision of the physiotherapist who will teach and insist on the correct methods of postural drainage and of breathing is probably the most important part of a palliative regime The simple suggestion to the patient that he should lean over the edge of the bed is useless

Riggins (1941) in a careful review of 100 patients with bronchiectasis says an estimation of the present status of our untreated and medically treated living cases based on their symptoms general and local conditions shows that 13 3 per cent are regarded as improved 46 6 per cent essentially unchanged and 41 1 per cent definitely worse than when first seen We have not succeeded in curing any case of well-developed bronchiectasis with medical measures including climatic treatment X ray therapy and bronchoscopy The treatment of bronchiectasis is surgical where major surgery is feasible and not contra indicated

The results of surgical treatment This must be reviewed in terms of mortality rate and the cure or relief of symptoms and both depend on the types subjected to operation Bilateral disease and the general condition of the patient have a far greater effect than age Before the 1939–45 war many surgeons were reluctant to operate on patients over 40 but this view is no longer held in fact a patient of 50 with unilateral disease may well be a better operative risk than a child of 6 with bilateral disease though children stand major thoracic operations with surprisingly little upset In the very young children however the post-operative treatment is difficult if the patient cannot co-operate by the intelligent use of coughing and young subjects show a higher rate of atelectasis in the remaining lobes than the older ones In a recent series of 210 resections for bronchiectasis (d Abreu and Brain) there were 5 deaths in the patients under 14 (105 operated on in this age group) and 3 in patients over that age (105 also in this age group were operated upon) there were however many more examples of post-operative atelectasis in the younger age group The ideal time for lobectomy in children is when they are old enough to co-operate in their physiotherapeutic management and young enough to forget rapidly the horrors of surgery perhaps the ages of 6 to 12 are ideal

Mortality rate This has steadily fallen with improvements in anaesthesia pre and post-operative treatment (especially with reference to the evacuation of the tracheo bronchial secretions by postural drainage ward discipline and methods of suction by *intranasal* catheter or by bronchoscopy) and in the actual technique of the resection which is greatly assisted by modern antibiotic and chemotherapeutic measures

In 1946 Dolley and Jones reported from a collected review of many surgeons figures that whereas the mortality rate in pulmonary resection from 1920 to 1939 was 18 per cent

the statistics of the 1935–39 period showed the mortality to be from 2 6 per cent to 11 per cent Since that date even better figures are available Holmes Sellors (1950) reported 6 deaths in 100 consecutive cases, Overholt (1948) reported only one death after 59 segmental resection operations, that being caused by the cut end of a fine stainless steel wire ulcerating into the pulmonary artery The Toronto figures of 80 lobectomies in 75 members of the fighting services with one death is an outstanding achievement (Laird, 1948) It may be stated fairly that modern techniques for resection of part of the lung (lobectomy or segmental resection) or of the whole lung should not carry a mortality rate much above 1–2 per cent In the last consecutive series of 100 resections at the Queen Elizabeth Hospital and the Children's Hospital, Birmingham, there has been only one death When it is remembered that bronchiectasis is a dangerous disease associated with severe disability, unhappiness and much ill-health, these figures justify the opinion that in the absence of contra-indications of a formidable nature, resection is the treatment of choice

TABLE V

MORTALITY FIGURES AFTER RESECTION FOR BRONCHIECTASIS

(July 1946–Dec 1950)

A L d'Abreu and R H Brain

Total number of operations, 210
(190 patients 92 under the age of 14, 98 over the age of 14,
20 patients had bilateral resections)

Pneumonectomy
Patients under the age of 14, 14 (2 deaths)
Patients over the age of 14, 25 (1 death)

Lobectomy or Segmental Resection
Patients under the age of 14, 91 (3 deaths)
Patients over the age of 14, 80 (2 deaths)
4 of the deaths were in patients with bilateral disease

Total Operative Mortality
i e deaths in Hospital, 3 8% approx
In 100 subsequent operations there has been only 1 death

Post-operative morbidity If all the diseased tissue is completely resected and the remaining lung tissue fully re-expands without empyema formation or without any area of atelectasis a cure will be obtained and this should be achieved in 80 per cent of patients Another 10–15 per cent should be greatly improved, the chief disability complained of in this group and in those of real failure being persistent thoracic pain and persistence of some sputum

(a) *Thoracic pain* This may be widespread over the operated side but more commonly is complained of along the line of the thoracotomy incision and extending obliquely downwards beyond the anterior limit of the healed wound, and is due to the operative trauma of the intercostal nerve and sometimes can be relieved by the para-vertebral injection of procaine in oil or by resection of the intercostal nerve

(b) *Persistence of sputum* This is due to four principal causes

(1) All the diseased segments have not been removed This is becoming increasingly less frequent as the result of better bronchography and a more accurate pre-operative evaluation of the bronchograms In the early days of resection surgery it was not unusual for an involved lingula or middle lobe to be overlooked largely because the iodized oil

filling of the bronchi was inadequate or because good lateral or oblique views of the filled lung were not obtained.

(2) Faulty re-expansion of the lung tissue Frequently the remaining lobes or segments fail to re-expand after operation or quite commonly they re-expand readily only to collapse later as the result of pent up bronchial secretions the result of inadequate cough This is far commoner in patients with bilateral disease for there is still a large reservoir of sputum after one side only has been operated upon The insistence on adequate post-operative cough aided by frequent change of position and with the constant help of the nursing and physiotherapeutic staff usually overcomes this retention of sputum If this is inadequate intratracheal suction or bronchoscopic aspiration is essential and its need can only be indicated by the frequent taking of post-operative radiographs In a few patients all efforts to obtain full and early re-expansion fail and these collapsed segments may lead to the continuous production of sputum and ultimately become bronchiectatic and require (if possible) further surgical resection Five of the resections in 210 operations for bronchiectasis (Table II) were carried out for the removal of permanently collapsed lobes after previous lobectomy (residual lobectomy) (see Fig 8 3)

(3) The result of empyema formation. With the substitution of dissection lobectomy (Blades and Kent 1940) for the old tourniquet method of resection and with the improvements produced by the use of antibiotic therapy this complication has become rare perhaps the most usual type is the formation of a small empyema around the bronchus stump (stump abscess) When this develops the bronchus usually opens and pus is coughed up which is usually blood-stained If the remainder of the lung has fully re-expanded this may not be a serious complication and the use of postural drainage bronchoscopic aspiration and chemotherapy usually obviate the need for formal drainage though this must not be delayed if the symptoms persist

The usual cause of post-operative empyema is undoubtedly the development of a bronchial fistula With the adoption of the technique of closure of the open bronchus which obviates the inclusion of any crushed tissue in the line of suture and the use of pre and post-operative chemotherapy this complication has become rare Of the 210 operations listed in Table II one pneumonectomy patient out of 36 who survived total lung excision developed a fistula and empyema 6 patients out of 171 lobectomies or segmental resections developed an empyema these were drained but 3 developed serious disease in the remaining lobe which required residual lobectomy The complication when it develops is therefore a serious one

In children especially the risk of empyema development is small in 91 operations of lobectomy or segmental resection on 78 patients under the age of 14 there were 3 deaths of the 75 survivors 2 developed empyema both the result of fistula The bronchial wall in children is easy to handle accepts sutures well and heals rapidly It is of interest to state that no post-operative intercostal drainage was employed in 60 of these resections This seems to indicate that whatever the merits or demerits of routine drainage may be it has little effect on the question of post-operative pleural empyema

(4) *Purulent bronchitis* Many patients with real bronchiectasis have a generalized associated bronchitis usually catarrhal but sometimes purulent There can be no guarantee that this condition will disappear completely after excision of the bronchiectatic area the combination is most usual in patients with the fusiform type of bronchiectasis If a conservative attitude is favoured in the treatment of bronchiectasis this type of disease deserves special consideration its assessment is not easy but usually *the symptoms of* constant coughing in a child who has generalized moist râles over both lungs calls for

caution Residence in mild climates away from the smoke and dust of large industrial cities may lead to great improvement and is of especial value in the months before lobectomy is undertaken

The pre-operative treatment. The patient is admitted at least a week before operation for pre-operative measures such as postural drainage and breathing exercises, improvement of the general condition by bed rest, a balanced diet, the administration of iron and the use of blood transfusion if there is significant anaemia. The patient can gain confidence in those who are to supervise the post-operative period and should be trained in the use of the face and nose oxygen mask and the oxygen tent From the first the necessity for pre-operative cough and postural drainage is emphasized and the need and reasons for continuing this after operation explained. If possible the patient should be placed between two satisfied convalescent patients Penicillin inhalation therapy is used in this waiting period and parenteral penicillin or aureomycin given for twenty-four hours before operation It is probably unwise to carry out lobectomy soon after lipiodol bronchography until the radiographs show that the main oil content has been expectorated

Care of associated infection of the para-nasal sinuses and of dental sepsis Many of these patients have infected nasal sinuses the opinion of an ear, nose and throat surgeon should be sought Illogical as it may appear, radical surgical treatment of these sinuses should be postponed until after resection of the affected lung tissue, for extensive nasal operations are badly borne by patients with bronchiectasis and carry a risk of accentuating lung infection Sometimes the sinus condition may clear rapidly after the lobectomy, but lesser measures such as antrum puncture wash-outs and the use of penicillin inhalation may be of value Gross dental sepsis should be treated before lung resection operations

The extent of resection in the treatment of bronchiectasis

If all the diseased tissue is removed the results are excellent in the absence of post-operative complications such as delayed re-expansion of the remaining lung tissue or persistent atelectasis The distribution of bronchiectasis has probably reached its final form by the time the disease has been diagnosed accurately by bronchography and the condition rarely spreads to other lobes, though increasing progressively in the affected areas Serious complications such as lung abscess, empyema or cerebral abscess may supervene at any stage, but this is unusual If the resections necessary to remove all diseased segments are too extensive the patient may be left as a permanent respiratory cripple, and in children extensive resection may inhibit growth and development For this reason the modern aim is to resect only those segments that are actually diseased and every effort is made to conserve healthy segments Frequently in bilateral bronchiectasis segments may be involved in all lobes, though usually the lower lobes, the middle lobe and the lingula are the areas implicated Often the apical segment of the lower lobe (dorsal lobe) on each side may be the sole areas of those lobes free from disease, and the bronchogram may show that they have undergone considerable hypertrophy, being larger in size than the remainder of the lobe Such segments may well be spared, the basic segments only being resected

1. Lobectomy. Unless there are completely healthy segments present the whole lobe should be sacrificed frequently in operations for bilateral bronchiectasis both lower lobes together with the middle lobe on the right and the lingular segment on the left must be removed In spite of such extensive resections the physiological and anatomical result may be extremely satisfactory, the main difficulty in such operative programmes being the danger of post-operative collapse in one or other of the upper lobes This is especially so in the post-operative phase after one side has been dealt with, because of the persistence of sputum

from the unoperated side The ideal patient for lobectomy has strictly unilobar disease but this is not common and in our series of 210 operations for bronchiectasis only 71 were of this type (see Table VI) The use of lobectomy for bilateral disease has greatly extended the scope of these operations

TABLE VI

TYPES OF RESECTION IN 210 OPERATIONS FOR BRONCHIECTASIS

Pneumonectomy

Patients under the age of 14	14
Patients over the age of 14	25

Lobectomy

	Patients under the age of 14 91 Resections	Patients over the age of 14 80 Resections
Left lower lobe and lingula	32	28
Left lower lobe	20	21
Right lower lobe and right middle lobe	11	13
Right middle lobe	10	10
Right lower lobe	4	2
Lingula only	3	1
Right upper lobe	—	1
Segmental resections	11	4

Of the lobectomies on patients under 14 years 4 were for congenital disease i e dissociated lobes 3 in the left lower lobe area 1 in the right lower lobe For those over 14 years 6 were for congenital disease etc 5 in the left lower lobe area, 1 in the right lower lobe All had aberrant arteries supplying them from the aorta

In many other clinics the proportion of segmental resection would be a good deal higher in this series the selection of patients considered suitable for segmental excision may have been too rigid influenced perhaps unduly by reports on the difficulty in securing prompt re-expansion of apical segments of the lower lobes after resection of the basal segments The excellent results after segmental resections have been described especially by Overholt Leigh Collis in Birmingham has an impressive series of very successful results in lower lobe disease in which a healthy apical segment has been preserved

Although a considerable number of patients with upper lobe bronchiectasis are seen the symptoms are usually insufficient to justify resection and the prognosis of bronchiectasis in these lobes seems to be good without surgical excision persistent haemoptysis however is an indication for their resection

TABLE VII

OPERATIONS IN BILATERAL BRONCHIECTASIS *

Total number of operations in patients with bilateral disease	59
Under age of 14 years	37
Over age of 14 years	22
Number of bilateral resections (i.e 20 patients)	40
Deaths	3
Under age of 14 years	1
Over age of 14 years	2
Number of unilateral resections in patients with bilateral disease	39
Under age of 14 years (1 death)	24
Over age of 14 years (no deaths)	15

* Since this was written 32 patients have been subjected to bilateral resections of lobes or segments without a death

2. Pneumonectomy. This operation is reserved for patients with a sound contralateral lung, the diseased side showing bronchiectasis so extensive that lobectomy or segmental resections would be useless It is best tolerated by young patients who have powers of rapid physiological adjustment and can be safely executed at any age under 14, even in the first years of life It is a dangerous procedure in middle-aged patients who have already developed severe emphysema in the " good " lung with a consequent hypertension in the pulmonary arterial tree, but may be justified because it removes a large pus-secreting area which further impairs the crippled respiratory system

3. Segmental resections. The employment of segmental resections is of particular value in bilateral bronchiectasis where the aim is to conserve all the normal lung tissue, and by this method patients are successfully treated even with segments involved in all lobes of the lung Frequently in lower lobe bronchiectasis the apical segment escapes

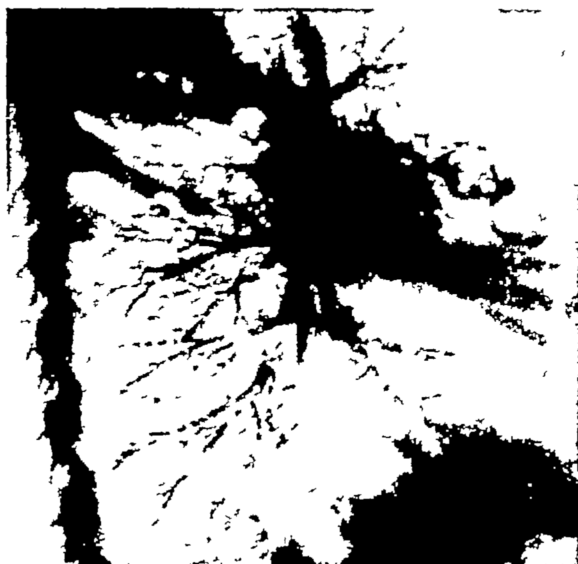


Fig 8 19

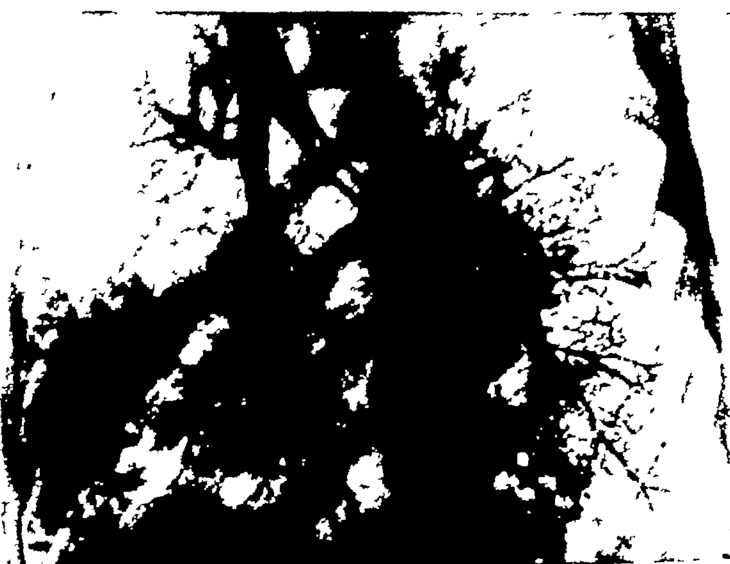


Fig 8 20

Fig 8 19 —Bronchogram of right lung showing bronchiectasis of the right middle lobe and the anterior and posterior segments of the upper lobe

Because in this child bronchiectasis existed in three segments in the left lung also, the extent of resection indicated on the right side was middle lobectomy and segmental resection of the anterior and posterior segments of the upper lobe, as the aim clearly is to conserve as much healthy lung tissue as possible as bilateral resections were required

Fig 8 20 —Left oblique view of bronchogram of right and left lung

Severe bronchiectasis of the middle basic segment (lateral basic segment) of the right side, the cause of constant bouts of pyrexia and sputum production An ideal indication for segmental resection which relieved all the symptoms

bronchiectatic changes and can be spared It is doubtful whether this operation is justifiable when the disease is confined to one lower lobe only, because the conserved dorsal lobe in an appreciably high proportion of patients fails to re-expand satisfactorily, but in bilateral disease it is often of great value to retain this segment

Excision operations

In addition to the operative details given below references to the anatomy of the bronchi and vessels of the lungs are given in Chapter 1 , the operation of pneumonectomy has been detailed in Chapter 12

1. Lobectomy

The pre-operative care, the position on the operating table and the anaesthetic requirements have been considered in Chapters 3 and 4 Different procedures are indicated for

different lobes The lower lobes the right middle lobe and the lingula segments are exposed by a wide posterolateral thoracotomy through the bed of the resected sixth or seventh ribs the increasing tendency to use the sixth rib bed instead of the seventh is based on the easier approach to the hilar vessels which counterbalances the difficulties encountered if there are strong basal adhesions to the diaphragm especially in the posterolateral depths of the phrenico costal sinus Access to the upper lobes is through the bed of the fifth or sixth ribs In all operations the exposure should be wide and this is best achieved by a resection of the entire rib from the transverse process to its costal cartilage

Lower lobectomy Any adhesions to the lobe in the region of the fissure and to the chest wall are freely divided if there is no free pleural space the divided edge of the periosteum and parietal pleura is held upwards and outwards by a series of small artery forceps The lung is then held down gently while the adhesions are divided largely by scissor dissection *As soon as sufficient space has been developed the chest is opened by* means of a rib spreader in children this is done effectively by the classical Tuffier retractor but in bigger patients the Tudor Edwards spreader or Price Thomas retractor (see p 77) is necessary As soon as the ribs have been spread adequately further adhesion severance is greatly eased and is accomplished by dividing with lobectomy scissors adhesions illuminated by a malleable chest light of the Nelson pattern placed deep to the fibrous bands this trans illummation at once discloses the presence of large vessels or lung tissue in the adhesions The major portions of the exposed lung are then covered with saline pads

The posterior end of the great oblique fissure is defined clearly this may involve division of interlobar adhesions or the section of bridges of lung tissue that frequently unite the upper and lower lobes at this site When the fissure has been defined freely the apex of the lower lobe is displaced forwards and possibly held in that position by a small Duval lung forceps

The *lower lobe bronchus lying above the inferior pulmonary vein is then seen through* the parietal pleura which is freely divided by scissor dissection It is an advantage to secure this bronchus as early as possible to avoid any risk of forcing muco-pus into the rest of the bronchial tree during manipulation of the lobe itself After the bronchus has been cleared of its sheath (this requires division and ligation of the bronchial arteries) a temporary clamp is placed across it well below its origin from the main bronchus Later a higher section can be done just before the occluding bronchial sutures are placed

If however the bronchus is a difficult one to expose and clear because of the presence of enlarged lymphatic glands or the presence of dense peri bronchial inflammatory fibrous tissue the attempt should be abandoned and attention directed to securing the pulmonary *arteries* These are exposed by dividing the peri vascular sheath covering the vessel as it lies in the depths of the fissure nearer to its posterior than anterior end The free division of this sheath often a difficult procedure in the presence of matted lymphatic glands is essential and the vessel should not be encircled by curved artery *forceps until the true* wall of the vessel has been exposed Once the sheath has been opened the anatomical arrangements of the vessels can be established The first vessel to be seen is usually the short stumpy branch passing to the apical segment (dorsal lobe) of the lower lobe on the right side opposite to this is the middle lobe branch (usually covered by a lymphatic gland) The artery to the lingula will be in a corresponding site on the left side the vessel below these tributaries then passes on into the main lobe where it may quickly divide into the segmental arteries No vessels should be tied until the anatomy has been fully displayed for the arrangements of the vessels may not follow the set pattern described above The chief danger arises when the main pulmonary artery curves down into the great fissure

giving off branches from its convexity to the dorsal lobe, lingula and lower lobe close to each other The actual securing, ligation and division of the vessels varies in each case it is frequently convenient to deal first with the dorsal artery and then the main lobar artery so that two sets of ligatures are needed instead of one A simple convenient technique is to pass a curved forceps of the Moynihan cholecystectomy type beneath the thoroughly cleared vessels and to grasp in its open tip a thread or silk ligature held down to it by a pair of long artery forceps, the cholecystectomy clamp is then closed and the ligature brought round the vessel and tied (see Fig 12 15 (*a*)) Before division of the vessel between two ligatures a fine thread or silk suture may be placed through the proximal end of the vessel below the first ligature as an added precaution

If the lingula or middle lobe is to be removed at the same operation the vessel supplying those segments should be clearly delineated, secured and tied at this stage as the fissure is well exposed and its limits retracted If the patient is in the lateral thoracotomy position the middle lobe bronchus and the lingular bronchus will be on a plane deeper to the artery and may be secured, clamped and divided before the lower lobe is retracted forwards towards the mediastinum for the next stage of the lobectomy, which involves the isolation and division of the main lower lobe bronchus and then of the large inferior pulmonary vein

The bronchus If this has not been secured before the pulmonary artery has been ligated and divided, steps for its isolation and division are now taken and this necessitates a thorough clearing of all peri-bronchial tissue by a mixture of scissor and swab dissection, this dissection must be such that the origin of the structure from the main stem bronchus is seen clearly If this is omitted the main stem bronchus may be endangered and the clamp must not be placed on the lower lobe bronchus until this has been isolated The lower bronchus is then divided above one clamp, the proximal open end being closed by interrupted sutures step by step as it is cut across (see Fig 12 15)

The bronchus is resected close to the parent stem to avoid leaving a stump with a poor blood supply and a small sump that might be a persistent source of infected bronchial secretions This end is best achieved by the use of a " suture of the open bronchus technique ", described on page 281 Alternatively if the bronchus is divided between two clamps, the one on the stump is removed and all crushed tissue together with any length of bronchus between it and the main bronchus is excised This will leave an opening into the main bronchus at the site of the origin of the bronchus which is closed by interrupted fine thread or silk sutures The simplest type of closure is the best and is achieved by through and through sutures tied sufficiently firmly to provide certain occlusion but not so tightly that necrosis of the bronchial wall will follow These sutures are left long and are subsequently re-threaded with needles so that a freely mobilized but pedicled pleural flap can be stitched over the sutured bronchial opening The lobe is then lifted forwards and upwards by traction on the bronchus clamp to facilitate the exposure of the inferior pulmonary vein

The inferior pulmonary vein After the division of the bronchus this vessel is seen just below it The overlying parietal pleura is divided freely, the areolar tissue cleared and the vessel is encircled by curved forceps which pick up ligatures passed down to it, as in the case of the pulmonary artery Extra length of vessel may be obtained by ligating separately the two main branches of the vessel as they emerge from the lobe After the inferior pulmonary vein has been divided the lobe is still attached by the ligamentum latum pulmonis which leads down from the inferior border of the vein to the mediastinal tissues, this is divided between clamps as vessels are invariably present in it Any remaining

adhesions between the lobe and the parietes and diaphragm are divided and the resected portion of the lung is removed

If the lower lobe is adherent to a middle lobe or a lingula that is diseased in the front part of the fissure these two segments are removed in one piece with the lower lobe after they have been isolated.

The chest is closed in layers and the remaining lobe fully re-inflated by the anaesthetist A drainage tube which will be connected to a water-sealed bottle is left in the pleural cavity and emerges through a small stab wound through the skin and an intercostal space below the main wound (see p 117)

Middle lobectomy The removal of the middle lobe for bronchiectasis is a relatively common operation When associated with a non tuberculous etiology it is usually a simple operation but the same cannot be said of resection for lobes collapsed as the result of tuberculous lymphadenitis or endobronchial tuberculosis In the latter instance the peri vascular sheath of the artery supplying the middle lobe may be obliterated by cirrhotic tissue and the presence of calcified nodes which render isolation of the vessel difficult

The exposure is usually through the bed of the resected sixth or seventh right rib the fissure between the lower and middle lobe is carefully exposed and the sheath of the main pulmonary artery fully opened Usually the artery to the middle lobe leaves the main artery opposite but at a slightly higher level than the branch to the apical segment of the lower lobe sometimes two branches are found After this vessel has been secured and divided the middle lobe bronchus will be seen this is isolated and divided between small curved clamps If gentle pressure is executed on the clamp on the distal bronchial end the middle lobe will start to peel away from its attachment to the upper and lower lobe pathological adhesions being divided during this process When the peeling process has proceeded for a few centimetres the middle lobe vein is seen on a plane anterior to the bronchus and is secured divided and tied Frequently this vein enters the pericardium as a separate trunk and an alternative method of securing it is to seek it on the mediastinal aspect of the middle lobe as that lies on the pericardium

The bronchus is dealt with in the way already described in lower lobectomy

Lingulectomy If the lingula is to be resected alone the procedure adopted is very similar to that for middle lobectomy but the artery lies at a somewhat higher level than that to the middle lobe for that reason a good exposure of the main pulmonary artery in the great fissure is essential once the lingular artery has been divided the bronchus is seen lying deep to it if the operation is conducted through the normal postero lateral approach this bronchus must be fully exposed before it is clamped as damage to the upper lobe bronchus is possible if its anatomical disposition is not fully displayed Once the bronchus has been divided the lingular vein will be brought into view when a little peeling has taken place this vein drains into the superior pulmonary vein

Upper lobectomy Although this operation is far more frequently used in tuber culosis than in simple bronchiectasis it is convenient to describe it here It is a more difficult operation than lower lobectomy because of the more complex arrangement of the arteries leaving the main pulmonary trunk

The chest is opened widely through the bed of the resected fifth rib On the right side the apex of the lobe is depressed downwards after all adhesions have been freed in resection for tuberculous disease this mobilization often involves an extra pleural dissection to avoid the risk of opening into tuberculous tissue Below the azygos vein the pleura is freely divided to expose the apical artery this is isolated divided and tied Deep to it the upper lobe bronchus is exposed cleaned and clamped. Once this bronchus has been divided

access to the superior pulmonary vein branches is eased this vein is then cleared carefully of its adventitious covering, this is essential as the main pulmonary artery is an immediate posterior relation to it When the vein has been secured and divided, the sheath of the main pulmonary artery as it descends to the lower and middle lobes is thoroughly opened, the smaller vessels supplying the anterior and posterior segments of the upper lobe can then be fully displayed and secured The dissection of the main pulmonary artery should be adequate enough to expose fully the middle lobe artery and that to the apical segment of the lower lobe these vessels should be constantly in view as the lobe is dissected free from any normal or pathological adhesion to the lower and middle lobes The chief danger in upper lobectomy is always to the main pulmonary artery which may be torn as the lobe to be removed is pulled upon if all small vessels supplying it have not been divided and tied

Left upper lobectomy is more difficult than on the right side because of the many small vessels that may leave the main pulmonary trunk, after it has swept round the upper lobe bronchus If as a first step the left main pulmonary artery is cleared and encircled by a thick linen tape, light temporary retraction of the vessel can be maintained while its branches to the upper lobe are secured the apical branch is dealt with as on the right side Before the upper lobe bronchus is clamped off the superior pulmonary vein and the branches of the artery beyond the bronchus are secured and divided these arteries vary greatly in number and can be found safely if the sheath of the main artery is thoroughly cleared.

The bronchus is then clamped and divided The lobe is held over to the mediastinum and the arteries to the posterior segment and to the lingula are secured The lobe is then removed and the bronchus sutured in the normal way

2. Pneumonectomy

Although occasionally a patient may present bronchiectasis in all lobes of one lung of such a distribution that multi-segmental resections may be employed with success, wide-spread disease throughout the lung, with a sound contralateral lung, is usually an indication for pneumonectomy This operation may be available to patients of all ages but the best physiological results are seen when the operation has been done on young children and the procedure is safe in the earliest years The operation is along the lines of extrapericardial dissection pneumonectomy for carcinoma as described on page 279

3. Broncho-pulmonary segmental resections (*see also* p 10)

Surgical techniques have been standardized for the removal of any broncho-pulmonary segments without damage to the adjacent healthy areas of lung tissue (Pilcher, 1944, Overholt, 1950), and great progress has been made since the original publication of Churchill and Belsey (1939) describing lingulectomy Segmental resection is especially indicated in bilateral bronchiectasis The commonest segmental resection practised is undoubtedly on the lingula process of the left upper lobe, but the recent practice of conserving the apical segment of the lower lobe (dorsal lobe) when the remainder of the lower lobe is diseased has gained wide popularity

Technical principles underlying segmental resection Each broncho-pulmonary segment has its own individual artery and bronchus, its venous drainage may be partly *to the neighbouring segment* There is an avascular line of cleavage between each segment, but the visceral pleura is a continuous sheet covering all segments The essential procedures in segmental resection are :

1 The accurate dissection in the hilum of the supplying artery and bronchus

2 The ligation and division of the artery

3 The clamping of the supplying bronchus followed by the inflation of the remainder of the lobe by increasing the positive intertracheal pressure this allows the segment to be accurately delineated as it will remain collapsed unless there is considerable air drift (see p 10) At this stage great attention is paid to the intersegmental vein this should be defined clearly and not damaged if it is tied the adjacent segment becomes passively congested and there may be haemoptysis in the post-operative period in addition to functional loss (see p 9)

4 The division of the pleura along the line of the intersegmental plane

5 The application of traction to the forceps applied to the divided artery and bronchus and the peeling out of the segment from surrounding healthy lung tissue by a mixture of blunt and sharp dissection (Clagett and Deterling 1946 Overholt *et al* 1950)

6 The avoidance of clamps and unnecessary suture on the healthy lung tissue which at first allows air to bubble out of the damaged alveoli but these soon become self-sealed The use of clamps causes unnecessary trauma to healthy lung tissue while suture of the raw areas may cause great loss of expandible lung tissue and considerable distortion of the lobe

7 The ligation and division of the vein or veins that are clearly seen during the course of the peeling out of the diseased segment

The operation of segmental resection The pre-operative attention the position of the patient and the type of anaesthesia used are governed by those principles that obtain for lobectomy The commonest segments to be removed are those of the lower lobe and the lingula

Resection of the basal segments, conserving the apical segment Excision of the lingula has been described on page 73 This is through the bed of the resected sixth or seventh rib a lower incision than this hinders easy access to the lung hilum When the retractors are in place and any obstructing adhesions have been divided the first step is to display fully the hilum in the great fissure If the lower lobe segments are to be resected and the apical segment of the lower lobe (dorsal lobe) is to be saved the posterior limit of the great fissure is fully exposed by retracting the two lobes by means of pledgelets held on long artery forceps Adhesions in the fissure are carefully divided and the adventitia over the pulmonary artery is held up and freely divided With careful dissection the loose areolar tissue is well cleared from the artery If the apex of the lower lobe is depressed downwards the first branch to be seen is the one proceeding to the dorsal lobe the main pulmonary artery continues downwards into the mass of the lower lobe Some times one single vessel can be cleared tied and divided between two ligatures but frequently the main artery gives off the branches separately and early and when this is the case they are dealt with seriatim If as is so often the case the lingula on the left and the middle lobe on the right have also to be resected the next step of the operation is to define isolate tie and divide their vessels typically they arise from the main stem in the fissure almost opposite to the branch to the dorsal lobe

When the arteries have been divided the bronchus is seen this requires to be cleared meticulously especially on its posterolateral aspect because here will be found the vein draining the dorsal lobe that is to be conserved The bronchus is then (there is 1 cm of it below the origin of the dorsal lobe bronchus) clamped just below the point of origin of the dorsal lobe tube and the lower lobe is held upwards and medially while the operator turns his attention to the posterior surface of the lobe and divides the pleura freely over the

inferior pulmonary vein This is freed deliberately of all fascial and areolar envelopments until the entry of the vein from the dorsal lobe is seen clearly and this must, of course, be preserved When the other tributaries of the vein have been secured and divided the anaesthetist inflates the lung until the air has distended the dorsal lobe this will demonstrate the point at which the airless lung of the segments whose bronchi have been clamped and divided meets the air-filled dorsal lobe Along this line the pleura is incised and then the lower lobe segments are peeled off the healthy tissue of the dorsal lobe by a mixture of blunt and scissor dissection When this has been achieved the lobe is only held by the ligamentum latum which is divided after its vessels have been clamped the bronchus is closed in the usual way by means of the open bronchus technique

Occasionally one segment only of the lower lobe requires resection, if this is so the artery and bronchus to the segment to be resected are carefully dissected The segmental bronchus and its artery are divided before any attempt is made to isolate the vein Once traction is applied to the forceps on the distal end of the divided bronchus the segment begins to peel out and the vein will be seen quite clearly and can be seized and divided

Resection of upper lobe segments The anatomical approach to these segments is described on page 10 The essential features are the exact display of the segmental artery and bronchus before any attempt is made to secure and divide them

The post-operative treatment. The principles of the post-operative management after resections for bronchiectasis have been discussed on page 88

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PART III

PULMONARY TUBERCULOSIS

CHAPTER 9

COLLAPSE THERAPY

The treatment of pulmonary tuberculosis is no longer purely passive In some types of disease life can be saved only by effective collapse therapy such as artificial pneumothorax or more extensive surgical methods In chronic progressive pulmonary tuberculosis with cavitation satisfactory collapse therapy or resection often provides the only hope In the modern sanatorium the physician from the start is preoccupied with the decision as to whether to employ collapse or resection measures and the choice of time for adopting them

The need for general measures

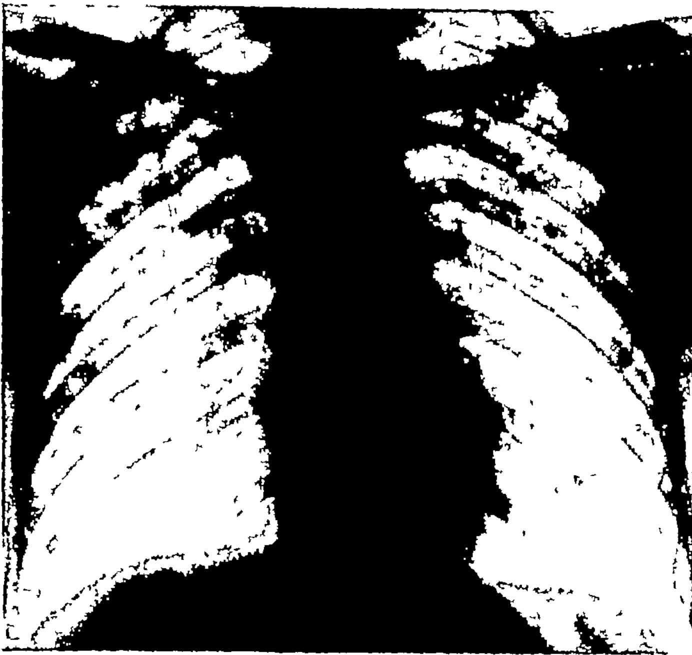
The essential need for rest a controlled life a good environment physical and mental well being suitable diet and chemotherapy is not minimized by the use of collapse therapy Sanatorium life often a most valuable treatment in itself prepares the patient for auxiliary methods such as collapse or resection procedures and frequently under its influence a patient admitted with a lesion totally unsuitable for surgical measures (including artificial pneumothorax) passes on to a stage when surgical procedures become feasible and indicated.

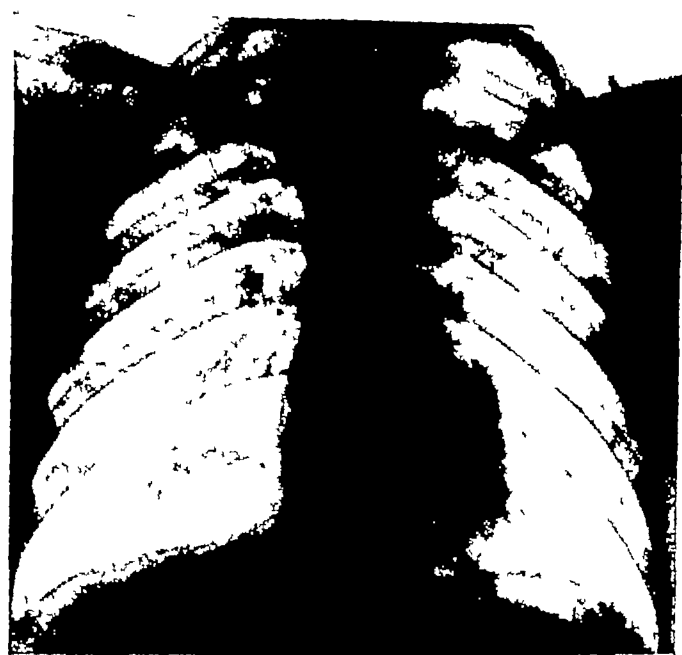
Chief contra-indications to surgical treatment

Far more patients with pulmonary tuberculosis come into this category than into those in which more active therapy is indicated but in a surgical work it is permissible to say that sanatoria have gradually changed from peaceful backwaters of conservative therapy into tuberculosis hospitals where active methods of treatment are extensively applied (Ustvedt 1947)

Conservative treatment by rest often absolute with complete confinement to bed is applied to early disease without cavity formation as in the primary infection or the re infection focus and achieves arrest of the disease in many patients it is used for acute or subacute disease in which the patient is toxic and pyrexial as the result of an exudative pneumonic process in the lung parenchyma

Pneumonic consolidation with active cellular and oedematous exudation into the alveoli produces a solid inelastic lung which can neither be compressed nor relaxed and is uninfluenced or worsened by artificial pneumothorax or thoracoplasty From the soft exudative areas toxins pass into the blood and lymphatic circulation often causing general systemic illness Accentuation and spread of the disease in the same lung or to the other one along the bronchial tree the lymphatic system and the blood stream may be encouraged by a disastrous misuse of collapse therapy Under bed rest sometimes with the aid of streptomycin and para aminosalicylic acid such patients often develop a resistance to the disease that enables the natural healing processes of resolution and fibrosis to overcome the acute pneumonic process If resolution is incomplete and mechanical distortions prevent healing the stage may be set for active auxiliary treatment During this slow





(a) (b)

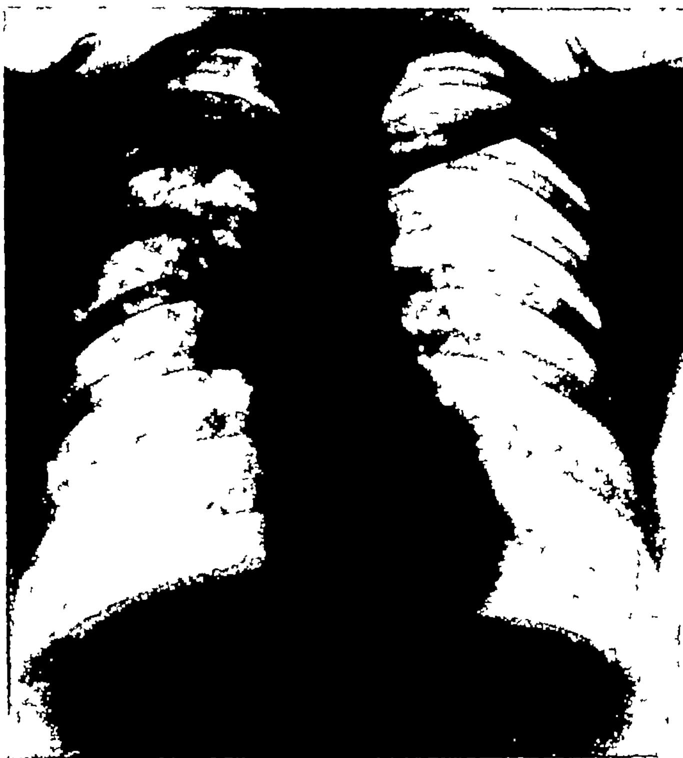
Fig 9 1

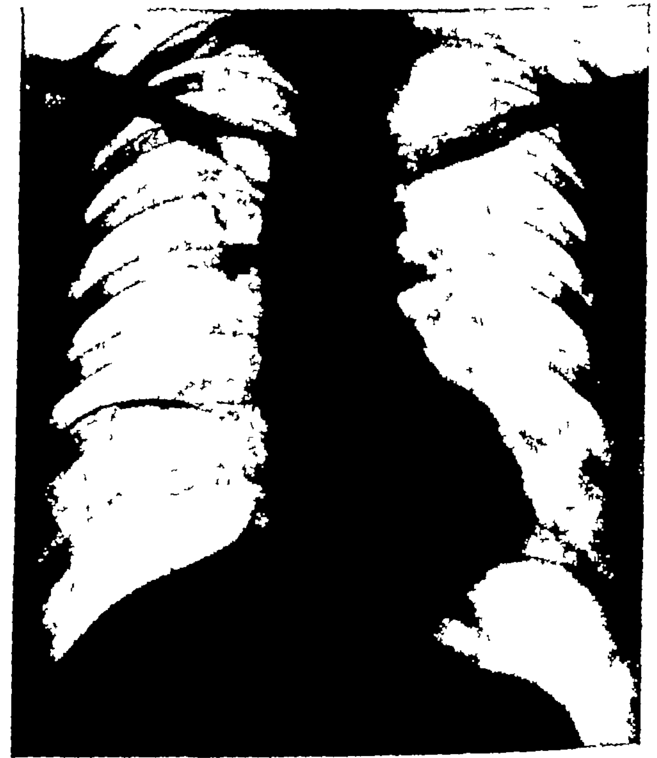
(a) Bilateral upper lobe disease

Acute type with multiple cavitation, patient toxic and pyrexial

(b) Radiograph of patient illustrated in Fig 9 1 (a) after one year's complete bed rest, six months of which were spent in a plaster cast

Considerable resolution with minor cavitation in right upper lobe now amenable to surgery This patient was treated before the streptomycin era





(a) (b)

Fig 9 2

(a) Right upper lobe, exudative disease, with a cavity below the clavicle

Patient toxic and pyrexial

(b) Radiograph of the same patient illustrated in Fig 9 2 (a) after bed rest, right phrenic nerve crush and a pneumo peritoneum

Notable healing and cavity disappearance

evolution from active to chronic tuberculous disease the possible application of collapse measures must constantly be in mind

Phrenic nerve interruption and pneumoperitoneum may be helpful before the exudative process has passed into the productive stage when fibrosis or resolution are becoming obvious perhaps this pathological evolution provides the most useful indications for these less severe collapse measures

Collapse therapy

The conception that a patient with pulmonary tuberculosis is suffering from a systemic distribution of tuberculous toxins and therefore requires general treatment may occasion a blind failure to recognize the essentially local nature of the tubercle bacilli habitat in a persistent cavity which prevents or delays an attack upon the important focus The statement that pulmonary cavities are a localized expression of a general systemic disease is an incorrect unwise and dangerous platitude patients with uncollapsed cavities die within three to five years after their radiological detection in 60 per cent of instances Modern practice insists on an attempt to close cavities in patients with signs of progressive resistance and of retractility of surrounding lung tissue unless the state of the remainder of the lung or of the opposite side prevents such measures Cavities undoubtedly can close and remain closed on bed rest and general treatment only but most of them fail to do so in established chronic disease

Each collapse or relaxation method has its own peculiar indication and no longer is there support for a step-ladder programme in which artificial pneumothorax phrenic nerve interruption and thoracoplasty are used in that order in the hope that one or other will succeed At the first consultation when collapse measures are considered the ideal choice may be a primary thoracoplasty or the radiological clinical or bronchoscopic appearances may indicate that no collapse measure will succeed and that resection of the lobe or lung affected may be the only hope of achieving success

The whole course of the patient s disease and the probable progress and outcome of the lesions should be envisaged so that auxiliary methods may be introduced not only at any time but at the right time with the aim of arresting the tuberculous process with the least possible loss of healthy functioning tissue

Collapse procedures

The following collapse procedures are available

(A) Intrapleural artificial pneumothorax.
(B) Surgical division of adhesions in an artificial pneumothorax
  1 Closed intrapleural pneumolysis.
  2 Open intrapleural pneumolysis
(C) Interruption of the phrenic nerve.
  1 Complete and permanent
  2 Temporary (phrenic crush)
  3 Combined with pneumo-peritoneum
(D) Thoracoplasty
(E) Extrapleural artificial pneumothorax
(F) Direct pressure collapse
  1 Plombage with paraffin or plastic material
  2 Oleo-thorax (p 250)

The more direct measures such as resection and cavity drainage will be discussed later

Effect on respiratory function of collapse measures

A surgeon is apt to judge the results of collapse treatment largely on the basis of the number of cavities closed, and the rate of sputum conversion The effects on function have often been neglected though a large amount of information is now available on this subject, and the need to preserve lung function as far as possible is becoming a guide to selection A selective thoracoplasty or resection is often more conservative of lung ventilation than a pneumothorax and provides good physiological results in direct proportion to the amount of alteration of the function of the chest wall and diaphragmatic movements acting on a pleural cavity that has been disorganized as little as possible

Any form of collapse therapy interferes with ventilatory function, as can be demonstrated by the lowering of maximum breathing capacity, thoracoplasty operations naturally interfere with the movements of the chest wall and also with the full range of the diaphragm It might be assumed that this would have more serious effects on the respiratory function than artificial pneumothorax according to Gaensler and Strieder (1950), this is not so From their studies of the maximum breathing capacity, residual air, ventilation on exercise and the breathing reserve and using bronchospirometry findings they have established a valuable estimate of the effects of the different collapse procedures In a series of patients whose total ventilatory capacity was estimated six months after the induction of a pneumothorax, the loss was 30 per cent in the average patient it was only 15 to 12 per cent after thoracoplasty In the same group of patients bronchospirometry showed a loss of 50–60 per cent after pneumothorax, contrasted with 20–25 per cent after thoracoplasty After the operation of phrenic nerve interruption or extrapleural artificial pneumothorax the loss was 10–15 per cent A pneumothorax maintained for over a year greatly impairs ventilation and oxygen uptake

This subject has been discussed more fully in Chapter 2

INTRAPLEURAL ARTIFICIAL PNEUMOTHORAX

Decrease in the use of artificial pneumothorax has been pronounced in the last ten years The aim is to provide temporary local rest to the lung, to decrease the size of the diseased area and to relax rather than compress it The early views attributed the beneficial effects of collapse therapy to immobilization and compression of the lung, and attempts were made to force the whole lung down to the mediastinum by the injection of air into an artificially produced pneumothorax, disastrous results both on the physiology of the patient and on the pleural cavity frequently followed The modern plan does not aim at compression-immobilization and the lung beneath a good pneumothorax will be seen radiologically and on physiological examination to be functioning quite widely The ideal is a selective relaxation of the diseased area which encourages the natural elasticity of lung tissue to produce a concentric shrinking of the diseased lobe or lobes Collapse can be achieved by artificial pneumothorax (Fig 9 3), local selective thoracoplasty (Figs. 9 4 (a) and (b)), phrenic nerve interruption (Figs 9 5 (a) and (b)), pneumo-peritoneum (Figs 9 6 (a) and (b)), or extrapleural pneumothorax (Figs 9 7 (a) and (b))

When the two layers of the pleura are no longer in contact the diminished expansion of the lung exerts less lateral traction upon the diseased tissue, which being deficient in elasticity will retract towards the mediastinum It is in this mechanical respect of selective collapse that artificial pneumothorax presents its greatest virtue

In a satisfactory artificial pneumothorax the lung separates from the parietal pleura most widely in the area of maximum disease this area shrinks concentrically and the

healthy lung tissue elsewhere because of its normal elasticity remains well aerated (Fig 9 3) This satisfactory result of a good pneumothorax in which the intrapleural pressures are left on the negative side follows if there are no adhesions between the parietal and visceral pleura and if the healthy lung tissue can remain well aerated If adhesions are preventing the collapse they may be divided surgically (pneumolysis—see below) and the pneumothorax made selective and perfect But if the lung tissue becomes airless (atelectatic) a serious problem arises

Atelectasis of a lung or lobe of a lung is dangerous for several reasons the common sequel is that fluid develops within the pneumothorax space (the same effect is common when atelectasis develops in other conditions e g post-operative massive collapse post-

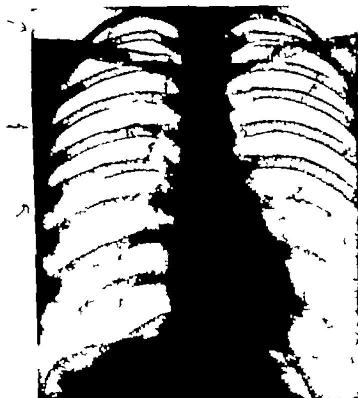
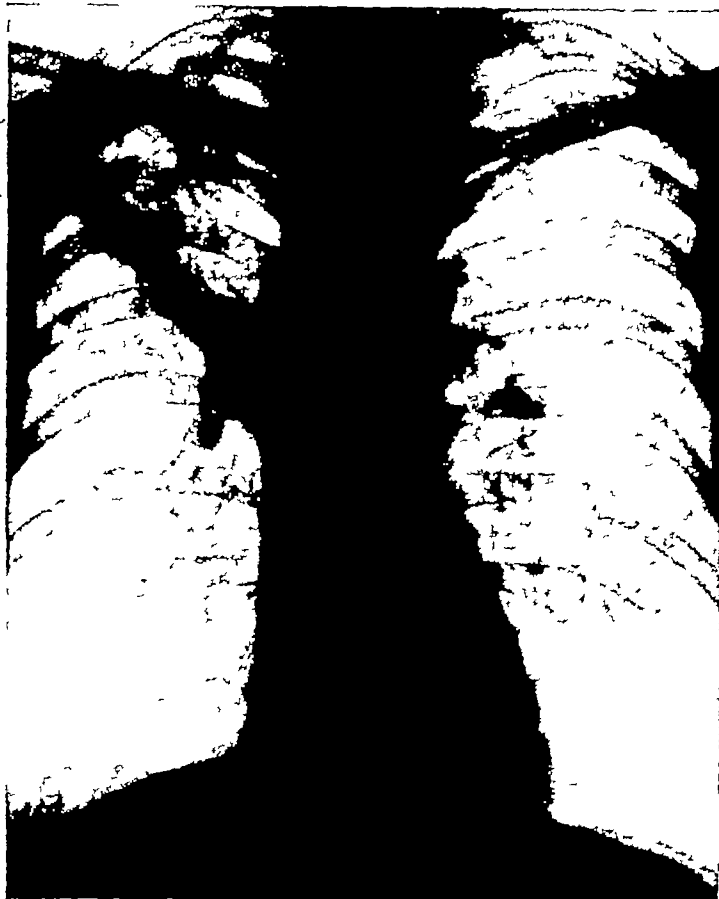


Fig 9·3 —An example of a selective artificial pneumothorax relaxing a diseased right upper lobe and leaving the lower lobe well aerated.

lobectomy collapse etc) In tuberculous disease this fluid may become infected with tubercle bacilli and/or pyogenic cocci and the dangerous condition of pyo pneumothorax is then present

The atelectatic area of lung is itself a potential ground for serious mischief the alveoli become full of exudate in place of air and the ciliary action of the bronchi is lost so that stagnation of bronchial secretions follow frequently with the rapid growth of organisms non tuberculous as well as tuberculous This is often reflected in the temperature chart which may show a rapid increase in pyrexia If the lobe remains airless for several weeks its bronchi dilate and irreversible bronchiectasis may follow

Atelectasis within an artificial pneumothorax readily seen on radiological examination requires urgent correction Sometimes an immediate adjustment of the pleural pressures may lead to prompt re-expansion but if this is not achieved the artificial pneumothorax should be abandoned and other measures considered



(*a*)



(*b*)

FIG 9 4

(*a*) Cavity in right upper lobe, partial atelectasis the result of endobronchial disease

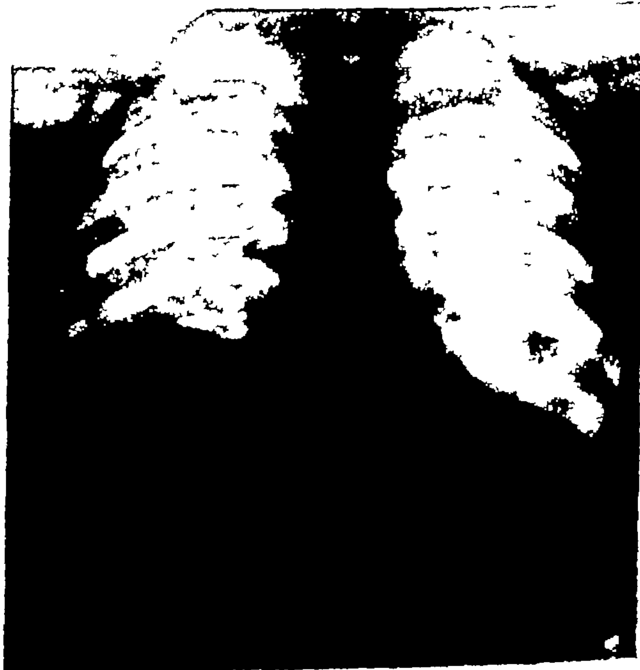
A case for resection could be made out, but this could still be carried out if a thoracoplasty failed to close this cavity Fig 9 4 (*b*) shows that the thoracoplasty sufficed

(*b*) Selective upper thoracoplasty for cavity illustrated in Fig 9 4 (*a*)

Sputum negative three years after operation



(*a*)



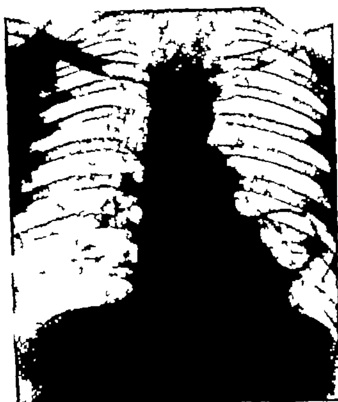
(*b*)

FIG 9 5

(*a*) A right phrenic nerve crush has been done for a large lower lobe basal cavity in a child of 11

(*b*) The effect provided by the elevation of the right leaf of the diaphragm in the patient whose cavity is seen in Fig 9 5 (*a*)

The cavity was proved closed by tomograph and the sputum has remained negative This radiograph was taken a year after that shown in Fig 9 5 (*a*) The lower lobe became atelectatic and required resection no tubercle bacilli were present





(a) (b)

Fig 9 6

(a) Left lower lobe cavity
(b) Selective collapse of left lower lobe cavity after left phrenic crush and pneumo peritoneum
The temporary result is excellent, but often such lesions still require resection





(a) (b)

Fig 9-7

(a) Right upper lobe cavity associated with endobronchial disease
(b) Right upper extrapleural artificial pneumothorax employed for the cavity lesion treated in Fig 9-7 (a)
The coll [illegible] for the temporary [illegible] of collapse provided for [illegible] allow for permanent coll [illegible] the patient however [illegible] satisfactory [illegible]

It is important to realize the danger of atelectasis in a pneumothorax because in former days we were encouraged to believe that bronchial occlusion of a lobar bronchus would often cause a cavity to disappear This was true enough, but the associated risk of the cavity rupturing if the atelectasis is within an artificial pneumothorax was overlooked A study of many of these patients shows that a collapsed segment or collapsed lobe in an artificial pneumothorax is dangerous if the sputum remains positive or a cavity is present



(*a*) (*b*)

FIG 9 8

(*a*) A highly dangerous artificial pneumothorax

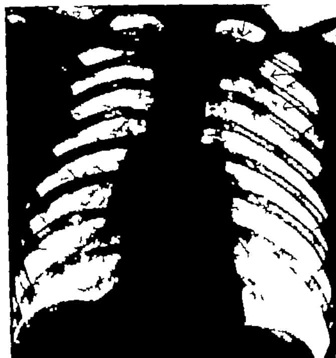
The cavity in the right upper lobe has enlarged when compared with pre-operative radiographs it is held up by an adhesion in the first interspace in the axilla the lower lobe is atelectatic The artificial pneumothorax was immediately abandoned and a right upper selective thoracoplasty performed with cavity closure

(*b*) After thoracoplasty

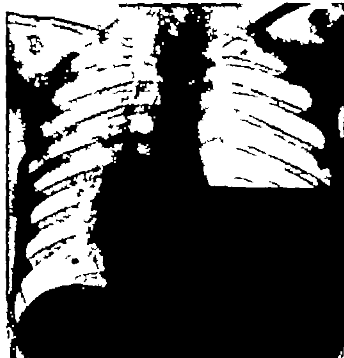
This condemnation of a maintained pneumothorax in the presence of atelectasis may appear harsh, many patients are alive and well today after an upper lobe cavity has closed in the presence of lobar atelectasis within an artificial pneumothorax

Coello (1951) in a thoughtful communication has indicated that the triangular upper lobe collapse within a pneumothorax gives good results as opposed to the disasters which may accompany a dangerous, round-shaped atelectasis which is solid and tense But a constant review of all types of collapse seen within a pneumothorax in the last twelve years has provided convincing evidence of the serious dangers of such a condition There are far safer methods of treatment now available if thoracoplasty, resection procedures and the correct use of antibiotic therapy are applied rationally and safely

The radiological story shown serially (Fig 9 9) describes the series of changes that followed in a boy of 19, treated by artificial pneumothorax for a small tension cavity in the



(a)



(b)



(c)

Fig 9-9

(a) Segmental atelectasis in right upper lobe within an artificial pneumothorax note a healthy, well-aerated, lower lobe and small cavities in the collapsed segment.

(b) A positive pressure tension pneumothorax with total atelectasis of the left lung has developed suddenly a month after the state of affairs depicted in Fig 9-9 (a)

(c) The position has been largely retrieved by left lower lobe decortication, left upper lobectomy (at which the cavity was seen to be ruptured into the pneumothorax space) and left upper thoracoplasty. Film taken a year after Fig 9-9 (b)

left upper lobe The first radiograph demonstrates a segmental collapse in the left upper lobe with a small cavity still apparent at the base of the atelectatic mass, the right course would have been to abandon the pneumothorax, probably with a small upper thoracoplasty or resection as the ultimate treatment A month later the common complicating catastrophe of massive collapse of the whole lung with fluid formation in the pleura had occurred

Attempts to obtain re-expansion failed and a total empyema developed which required frequent aspirations, the fluid containing tubercle bacilli, the intrapleural pressures became positive a few hours after each paracentesis, evidence of a broncho-pleural fistula After several months of illness the chest was opened, the lower lobe decorticated and a left upper lobectomy carried out It was obvious from the operative finding that a cavity in that upper lobe had ruptured into the pleural cavity The lower lobe re-expanded and an upper thoracoplasty was then performed to diminish the size of the left hemithorax, progress was slow but satisfactory and entailed an 18 months' stay in hospital which, combined with many aspirations and three major operations, was a heavy price to pay for an injudicially maintained pneumothorax.

Endobronchial disease as a factor producing atelectasis

Atelectasis in patients with a positive tuberculous sputum may be seen in a segment, a lobe or the whole lung, in primary tuberculosis a collapsed lobe may be produced by bronchial occlusion caused by gross pressure from enlarged tuberculous glands or from their ulceration into its lumen The dangers of atelectasis in a pneumothorax have been mentioned Collapse of the parenchyma of a lung may be due to endobronchial tuberculous granulation tissue Tuberculous bronchitis may be present in the absence of radiological changes in the lung and is a rare but important cause of a positive sputum under such conditions Such lesions can often be detected by bronchoscopy

Endobronchial disease is present in patients with "tension" cavities, the disease may be well away from a lobar or segmental bronchus, affecting only the bronchus draining the area of cavitation In such the endobronchial lesion acts as a valve mechanism by reason of its oedematous granulation tissue During inspiration the bronchi dilate and air can pass into the cavity With expiration the bronchial wall contracts and the lumen, already partially filled with tuberculous tissue, narrows to such a degree that the air entrapped in the cavity cannot escape and a tension or balloon cavity develops (Coryllos and Ornstein, 1938, Price Thomas, 1942) The use of artificial pneumothorax in such a patient may increase the effects of this ball-valve mechanism and the cavity will often enlarge under the influence of the increasing air pressure

Under such circumstances the artificial pneumothorax should be abandoned although occasionally it may be "manipulated" as follows air is taken off from the pneumothorax space until the lung is almost re-expanded and then at a week's interval the lung is again pushed down towards the mediastinum and the air withdrawn a day or two later Occasionally this may be followed by satisfactory closure of the cavity The reason for this is that the manipulation may cause complete occlusion of the draining bronchus or possibly reopen it so that the tension effects of the entrapped air are completely dispelled

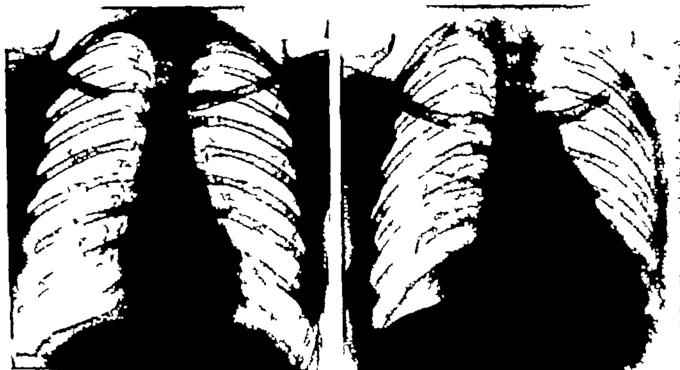
Usually, however, the safest course is to allow the lung to re-expand, in a few happy instances this may be followed by cavity closure because of the sudden alteration in the mechanism of the draining bronchus But most usually subsequent thoraco las resection will be required

Although recognition of the not infrequent involvement of the bron disease was widespread because of the work of Coryllos, Rafferty (1948)

the serious problems that often followed pneumothorax when applied to this group of patients He studied 40 unselected consecutive patients in whom pneumothorax therapy was applied for the treatment of parenchymal disease and in whom bronchoscopy proved that bronchial lesions were present The course of the disease was almost unbelievably bad

	Cases
Discharged as apparently arrested	13
Discharged as quiescent	7
Uncontrolled still in hospital	3
Died	17

But the complications noted are of even greater importance for in this group of 40 patients 17 developed atelectasis 7 had anaerobic infections 17 proceeded to empyema formation and 9 had unexpandable lungs These last two complications generally would be considered as graver states than the original lesion calling for pneumothorax and indeed



(*a*) (*b*)

Fig 9-10

(*a*) Radiograph showing a small circular cavity in the right second rib area The only indications that this might be due to endobronchial disease were (1) the patient complaint of wheezings in the right upper chest and (2) the circular outline of the cavity

(*b*) After the induction of a pneumothorax the small cavity shown in Fig 9-10 (*a*) has ballooned immediately An example of the effect of pneumothorax on cavities with endobronchial tubercular granulation tissue in the bronchus draining the cavity A strong indication for discontinuing the pneumothorax.

of the 17 empyema cases 13 died and of these only 3 had advanced pulmonary disease before the pneumothorax

Rafferty s condemnation of artificial pneumothorax as a treatment for lung disease associated with bronchial lesions has led to an almost complete disappearance of empyemata in sanatoria in this country and to the prompt recognition of atelectasis and its correction as soon as possible when it develops within a pneumothorax

Endobronchial disease as the cause of bronchiectasis

A severe tuberculous bronchitis may produce such stenosis of a main bronchus or of a lobar bronchus that gross bronchiectasis of the lung or the lobe ensues This is usually seen in long-standing disease and often there is an associated cavity It is not uncommonly seen when a pneumothorax has been induced for a cavity due to endobronchial disease which does not respond to the treatment , in this type of disease the previous aerated lobe or lung becomes atelectatic and fluid develops in the pleural cavity These patients require resection operation if the other lung is sufficiently stable to allow this radical measure



(*a*) (*b*)

FIG 9 11

(*a*) Atelectasis of left lung in a pneumothorax

Bronchial tuberculosis in main bronchus effusion in pleural cavity

(*b*) After left pneumonectomy

The recognition of bronchial disease

The use of bronchoscopy before induction of a pneumothorax is an obvious help, but apart from this certain clinical and radiological features are of value

An element of a " wheeze " in the cough is often unduly troublesome and frequently non-production of sputum is noteworthy , the symptoms are more severe than the radiograph would indicate probably because of the effect of sputum retention distal to the lesion Occasionally in bronchial disease the sputum is positive and yet there is no radiological indication of its source The X-ray photographs may show an area of collapse often segmental and often mistaken for interlobar thickening or effusion, and there is frequently a definite increase of shadowing in the peri-hilar region (" the hilar flare ")

It would be unwise to state that these features preclude the use of artificial pneumothorax *at any stage* If the bronchial disease clears with a regime of bed rest and possibly under a course of streptomycin and para-aminosalicylic acid, a pneumothorax, if still required for a parenchymal lesion, can be induced.

The treatment of parenchymal lesions associated with bronchial disease

(a) *Bed rest and chemotherapy* For lesions that might heal without collapse or resection procedures the most rigid rest should be enjoined and even in the absence of laryngeal involvement it is often of value to enforce the whisper rule, talking requires a moderately full use of bronchial function namely enlargement of the bronchus on inspiration and contraction on expiration and any measure that lessens this is worth while The decision as to the use of streptomycin and para aminosalicylic acid is difficult in the absence of cavitation and when there is reason to suspect that the bronchial disease is not yet in the chronic fibrotic stage chemotherapy should be used When cavitation is present and the assumption that surgery either in the nature of thoracoplasty or resection will probably be applied it may be wiser to withhold streptomycin until a fortnight or so before operation is carried out But each individual patient will require careful consideration as to the applicability of chemotherapy and many outstanding results have followed its use in these conditions

(b) *Operative treatment—thoracoplasty or resection or a combination of both?* If a circular cavity due to tuberculous endobronchitis is not closed by conservative measures treatment will be similar to that for any resistant cavity upper lobe cavities without atelectasis do well after thoracoplasty and apicolysis if the other lung is sound The advantage of this type of collapse over pneumothorax relaxation is the avoidance of the serious complication of empyema In addition since the collapse so obtained is not so concentric as in pneumothorax the lobar bronchus is not sufficiently kinked to produce atelectasis and the subsequent risks of suppurative bronchiectasis are less But transcending all these theoretical advantages is a cavity closure rate of 85 per cent or over after upper thoracoplasties with apicolysis This is vastly superior to the results that follow pneumothorax in this type of disease

A cavity in a collapsed upper lobe is often best treated by lobectomy usually followed by a small thoracoplasty to prevent over-distension of the remaining lower lobe an upper thoracoplasty may be employed as the first procedure to be followed by lobectomy if the sputum remains positive

For lower lobe cavities due to endobronchial disease thoracoplasty is quite unsuitable and if a temporary phrenic paralysis with pneumo peritoneum (Figs 10 12) fails to close the cavity lobectomy or segmental resection is indicated in the absence of obvious contra indications such as prohibitive disease in the upper lobe or in the other lung such contra indications may disappear with bed rest and streptomycin therapy

The chief indications for artificial pneumothorax

Essentially the treatment should be of temporary nature i e about two years and should not be advised if the radiograph indicates a lung lesion requiring permanent collapse Before a pneumothorax is induced an attempt should be made to estimate the probable physiological and anatomical condition of the lung after it has been abandoned The radiological appearances often indicate which lungs will remain inexpandable or functionless after a therapeutic pneumothorax

The advice that a pneumothorax should only be maintained for 1–2 years may be guided somewhat by surgical prejudice and many tuberculosis physicians would disagree and give figures indicating cavity reopening after the abandoning of re-fills If however a cavity does reappear under these circumstances it might well be argued that the original choice of treatment was faulty and that permanent collapse or resection would have served the purpose better

The end-complication of an "unexpandable lung" is a serious one, the mediastinum becomes distorted as its contents swing into the pneumothorax side, and the "good" lung becomes emphysematous, both factors having a serious effect upon the physiological function of the lungs and heart. Moreover, the pneumothorax space will tend to fill with fluid which often becomes infected

Breathlessness is a common symptom unless the re-fills are continued indefinitely and although this is possible in many patients it is far from being ideal Pneumothorax is inadvisable for large apical cavities, for extreme fibrocaseous disease and for patients with a tendency to "atelectasis", e g those with tuberculous tracheo-bronchitis Moreover as a general rule only the perfect pneumothorax should be retained, for a long experience of disasters of ineffective pneumothoraces where the collapse is non-selective, hindered by indivisible adhesions or associated with atelectasis, has indicated that the complications are too serious to be risked The commonest cause of a tuberculous empyema is a poor pneumothorax and in the modern sanatorium this condition is almost unknown

If a pneumothorax is ineffective the decision to abandon it should be made early, usually in a matter of days or weeks, though often the decision cannot be made until after thoracoscopic examination, when adhesions are seen on the radiograph The grave dangers of atelectasis and of fluid formation are best avoided by the prompt re-expansion of the ineffective pneumothorax

(I) Cavities. The main indication for pneumothorax therapy is a lung cavity without dense walls and surrounded by reasonably healthy tissue or parenchyma capable of re-expansion If the disease is suitable in other respects it is unwise to delay this treatment too long in the hope that less active measures will suffice, for the cavity itself is a daily menace to the rest of the lungs and is most likely to close with a pneumothorax In practice few tuberculous cavities close spontaneously and undue emphasis may be placed on the odd startling instance of such a happy result If, however, there is a pneumonic change in the lobe containing the cavity an early artificial pneumothorax may be disastrous, as atelectasis and fluid formation may follow The existence of a laryngeal lesion is often an encouragement for pneumothorax if that will control the pulmonary lesion

The site of the cavity. Upper lobe cavities are the most suitable, often the lower lobe cavity is a tension one associated with endobronchial disease which pneumothorax not only fails to close but often produces atelectasis. The modern trend for lower lobe cavities is to employ a phrenic nerve crush, often with a pneumo-peritoneum, the possible need for resection being borne in mind if these fail

Crofton's (1949) analysis of the results obtained by artificial pneumothorax in 44 patients out of a series of 55 with cavities in the apex of the lower lobe does, however, give a more encouraging picture of this type of treatment than is usually present Thirty-three of the patients had good evidence of cavity closure three years at least after the pneumothorax had been started Artificial pneumothorax had been used in 17, in 12 it had been assisted by adhesion section, and in 8 by adhesion section and phrenic interruption, while in 7 instances phrenic interruptions had been the sole auxiliary interference In this series pleural effusion and empyema were said to be no commoner than in pneumothorax for other lesions

Pneumothorax combined with hetero-lateral thoracoplasty Since patients with a cavity on one side, suitable for collapse therapy of which the most promising may be a thoracoplasty, and with evidence of infiltrative tuberculosis on the better side, do badly unless the cavity can be closed, many patients are submitted to rib resections with an efficient contra-lateral pneumothorax, usually of a temporary nature This combination is well borne if the respiratory function is adequate and if the pneumothorax is a strictly selective and satis-

factory one of a 'shallow' nature Bilateral collapse therapy has peculiar hazards of its own the greatest being the development of effusions or of a 'spontaneous' pneumothorax developing into the therapeutic pneumothorax such accidents have grave effects upon the function of the lung on that side For this reason the so-called 'protective' contra lateral pneumothorax for a minimal lesion of the infiltrative type should not be advised hastily this may heal better by bed rest and chemotherapy up to the point when contra lateral thoracoplasty is possible The risk however is justified if there is a hope of dealing with minor cavity formation on the so called good side



(a) (b)

Fig 9·12

(a) Although far from being an ideal left pneumothorax, a cavity in the left upper lobe has been controlled sufficiently to allow a small thoracoplasty to be done for the right upper lobe cavity
(b) The right upper lobe cavity seen in Fig 9 12 (a) has been closed by a small thoracopla ty

(II) Infiltrative disease The question of artificial pneumothorax treatment in these conditions is a difficult and controversial one and bed rest alone is not always sufficient though certainly it is indicated in patients with primary infection with enlarged hilar glands and pulmonary infiltrations Past experience showed that although a pneumothorax free from adhesions was often obtained the results were doubtful moreover a pneumothorax once satisfactorily established should be maintained for two years a high price to pay for a lesion often cured by bed rest

In patients with infiltrative disease without a cavity but with a positive sputum a pneumothorax is indicated if there is no improvement after three months bed rest as it may arrest the disease and prevent cavity formation It is of value when a thoracoplasty is to be done for a cavity on the other side At the time of writing many phthisiologists are advocating small segmental or sub-segmental resections of 'minimal' lesions that have failed to improve after 6–9 months bed rest as the after histories of such patients often indicate disturbing sequelae of progression

(III) Bilateral pneumothorax for bilateral disease. The patients suitable for this difficult therapy usually have cavities in both upper lobes of recent duration and with a considerable amount of healthy lung tissue in both lungs If the lower lobes have anything but minimal disease the institution of bilateral therapy should rarely be practised

Since bilateral disease usually follows pulmonary tuberculosis of long standing, adhesions frequently prevent a good pneumothorax , adhesion section is needed in over 50 per cent of patients with bilateral pneumothorax The number of patients therefore suitable for bilateral pneumothorax is strictly limited

The extent of the disease may be so advanced that a satisfactory respiratory function cannot be maintained after bilateral therapy and these patients require a full study of their respiratory physiology Especially important would be the estimation of disproportion between circulation and ventilation

It has often been noted that the production of selective collapse by the division of adhesions has led to improvement of respiratory function The need for selective collapse in bilateral pneumothorax is even more evident than when the treatment is unilateral, for every area of normal lung tissue must be allowed to function as normally as possible At times risks must be taken when active collapse measures are employed for bilateral disease the dangers of a potentially unstable pneumothorax must be weighed against the risks inherent in the natural history of the disease , under certain circumstances it is justifiable to employ pneumothorax therapy when the contra-indications to such a treatment seem to be strong

The treatment of the complications of pneumothorax

Most of the complications of pneumothorax are preventable by good selection of patients and by a constant appreciation of the dangers of atelectasis and fluid development in the pleura The incidence of complications will be further lessened if adhesion section is practised whenever bands are seen going to the diseased area of lung or the pneumothorax is abandoned if atelectasis develops or fluid forms The rupture of a cavity into the free pleural space is rarely seen today, but if it develops its treatment should be urgent, the ideal method being an immediate resection of the lobe (see p 237)

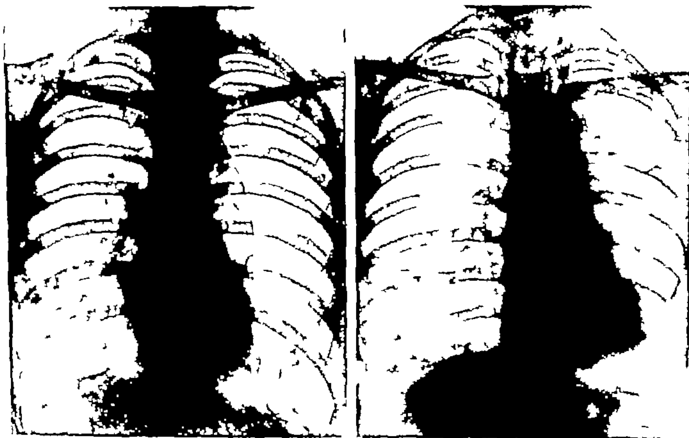
Effusions Pleural effusions may develop before or after adhesion section, the transient, innocuous ones being treated by aspiration but the rapid re-accumulation of fluid is an indication for re-expanding the lung, as the dangers of pyopneumothorax or of inexpandable lung are great (see p 195) The treatment of tuberculous empyema is long and difficult and is discussed fully elsewhere

Spontaneous pneumothorax Spontaneous pneumothorax into a pneumothorax space is usually due to rupture of an emphysematous area in the collapsed lung, often in association with adhesions After the immediate ill-effects have been treated by repeated withdrawals of air or the use of an in-dwelling needle leading to a water-sealed drainage system, a thoracoscopy is indicated and at this examination any adhesions leading to affected areas of lung are divided, as frequently the air leak comes from a tear in the lung parenchyma at their base If there is extensive emphysema present the pneumothorax should be abandoned and this may have to be achieved by the use of chemical pleurodesis (see p 509) If an empyema develops it is dealt with as described on page 249

Haemothorax A spontaneous haemothorax is a rare but serious complication which accompanies the tearing of undivided adhesions In the first 12–24 hours the treatment is quiet, enforced by the use of morphia and absolute rest if the haemoglobin falls below 70 per cent a slow blood transfusion is set up After this period the haemothorax fluid

should be aspirated and the pneumothorax usually abandoned If however the haemothorax is small and easily dealt with by aspiration thoracoscopy will be indicated if there are adhesions still present and the reasons for continuing the pneumothorax are sound. A temporary phrenic crush and a pneumo peritoneum may be required if the lung will not re-expand rapidly when a decision has been made to abandon the pneumothorax.

Atelectasis The development of opaque airless lobes or segments must be regarded as a complication and the seriousness and treatment of this has been discussed If atelectasis develops rapidly the intrapleural pressures may require immediate re-adjustment as altera-



(a) (b)

Fig 9·13

(a) Radiograph of a woman of 20 five years after a pneumothorax had been induced. All attempt to obtain re-expansion had failed.

(b) One year after decortication: the lung has fully re-expanded. Its function is no doubt poor but the dangers of late empyema and the need for repeated re-fills ha been [illegible]

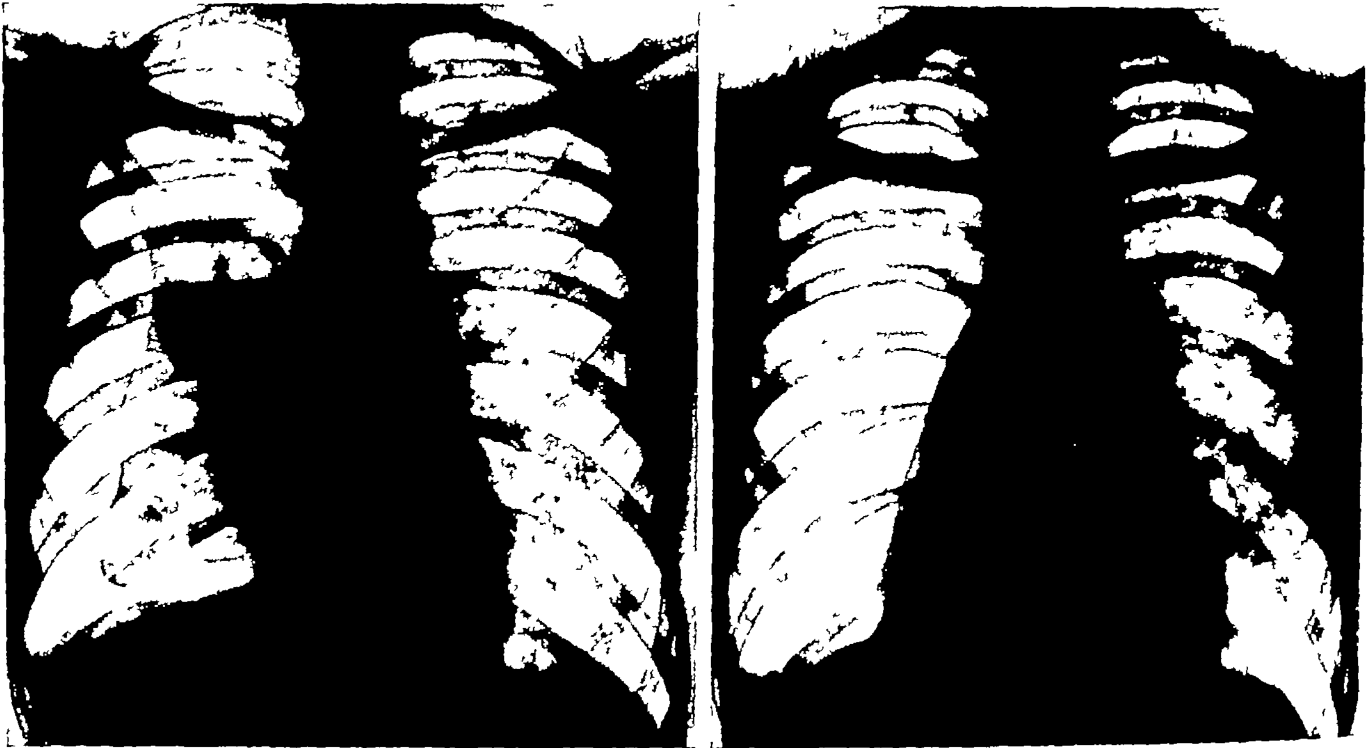
tion of the line of the bronchus may lead to immediate re aeration If the rapid development of an opaque lobe is associated with pyrexia bronchoscopic suction is often indicated whether the patient is undergoing pneumothorax treatment or has just been operated on for the performance of a thoracoplasty or resection

The unexpandable lung Since the aim of pneumothorax treatment is a temporary selective collapse which allows the lesion under consideration to heal the failure of the lung to re-expand when healing has occurred must be regarded as a complication which indeed may be followed by an empyema and by emphysema of the opposite lung which may be the cause of a fatal cardiac condition (Cor pulmonale)

Unexpandable lungs are due (1) to faulty selection of patients in which a temporary

collapse method has been used for a lesion requiring persistent collapse or resection, (2) to the presence of endobronchial tuberculous disease which contracts to produce a bronchostenosis, or (3) to the development of a thick cortex or organized fibrinous material in the pleura this is often associated with an empyema and the treatment of this by pulmonary decortication or thoracoplasty is considered later

The lung may fail to expand because of stenotic tuberculous bronchial disease or because of extensive parenchymal disease, and it may be wiser to proceed to thoracoplasty than to allow the lung and mediastinum to swing right over when the pneumothorax is



(*a*) (*b*)

FIG 9 14

(*a*) Atelectasis of right upper lobe with a cavity and a "free" lower lobe
Dangerously tempting for adhesion section!

(*b*) Same case four months after adhesion section
Although the cavity has closed the right lung is atelectatic and in great potential danger, a better result probably would have followed re expansion of the A P and an upper thoracoplasty

abandoned Stenotic bronchial disease causing a bronchiectatic or destroyed lung often requires a pneumonectomy

Whether the lung is unexpandable from avoidable or unavoidable causes it is unwise to attempt re-expansion if this can only be achieved by gross displacement of the mediastinum to the treated side, as this may lead to severe dyspnoea and over-distension of the good lung The decision should then be made as to whether the pneumothorax should be maintained indefinitely or be replaced by a permanent thoracoplasty, aided occasionally by a decortication of the underlying lung A pneumothorax so maintained may be satisfactory and patients have been maintained in comfort and health for periods of ten years and longer the development of fluid, however slow, is a serious sequel and usually indicates the need for major surgery Such operations will be imperative if the fluid becomes purulent

The development of a thick organized fibrinous envelope over the collapsed lung may be the cause of failure to re-expand and under certain rigidly established criteria the ideal treatment may be a lung decortication

Such a measure will only be considered if the lung parenchyma is good the sputum negative and the pre pneumothorax radiograph showed a localized extent of disease noted on later films to have been rapidly controlled by the pneumothorax

Adhesions and their treatment

Selective collapse is impossible if the diseased area of the lung is held to the chest wall by adhesions if thoracoscopic division is not possible it is unwise usually to persist with a pneumothorax *carrying the risk of empyema formation* particularly dangerous is the case in which an atelectatic upper lobe cavity is held open by adhesions and in which a normal lower lobe is completely free from diaphragmatic attachment Such a lung has a greater tendency to develop an atelectasis in this normal lower lobe followed by effusion (Fig 0 14)

In general an artificial pneumothorax with adhesions present is unsatisfactory not only because of a high complication incidence but because of ultimate poor results In practice the complications that follow include effusions (serous or purulent) atelectasis of the adherent or free lobe spontaneous pneumothorax from the tearing of lung tissue at the base of the adhesions and rupture of the cavity itself

The constant pull by the adhesions on the underlying diseased area during each inspiration is the negation of rest and the tension so developed is aggravated by increased lung movements as exercise or coughing cause violent changes in intrapleural pressure Since adhesions develop over areas of disease it is these that are subjected to the stresses and strains of undivided adhesions Since in over 50 per cent of successfully induced pneumothoraces adhesions are present it is clear that such treatment should not be employed unless facilities for adhesion section are available

Many published figures show that the final results of pneumothorax therapy are infinitely better in patients with anatomically perfect pneumothorax spaces than in those with adhesions however satisfactory the effects may have been in the latter group while the pneumothorax was in actual use (Livingstone 1939)

Fortunately the operation of thoracoscopy is available and can be carried out under local anaesthesia Some tuberculosis physicians insist on a thoracoscopy in all established pneumothoraces as radiology may overlook the presence of adhesions in a pneumothorax If a pneumothorax is inefficient and the adhesions shown on the radiograph are such that successful division is likely the operation should not be delayed and the usual time at which to undertake thoracoscopic inspection is from three to six weeks after induction The practice of stretching adhesions by increasing the size and pressure of the re fills has been abandoned for the risk of producing tearing of the lung is considerable and in the days when this method was practised spontaneous pneumothorax and effusions or rarely haemorrhage were seen

An effusion in the artificial pneumothorax space before the thoracoscopy is not necessarily a contra indication to operation if only a small amount in the costophrenic angle it should be aspirated and examined for tubercle bacilli if these are present the artificial pneumothorax should be abandoned

Thoracoscopy

The operator has the choice of two instruments

(*a*) The Single Puncture Thoracoscope
(*b*) The Double Puncture Thoracoscope

The double puncture method. Rather outweighing the popularity of the single puncture instrument, the use of two cannulae, the original plan of Jacobaeus the pioneer of thoracoscopy, is more favoured, because of the wider range of vision and the larger

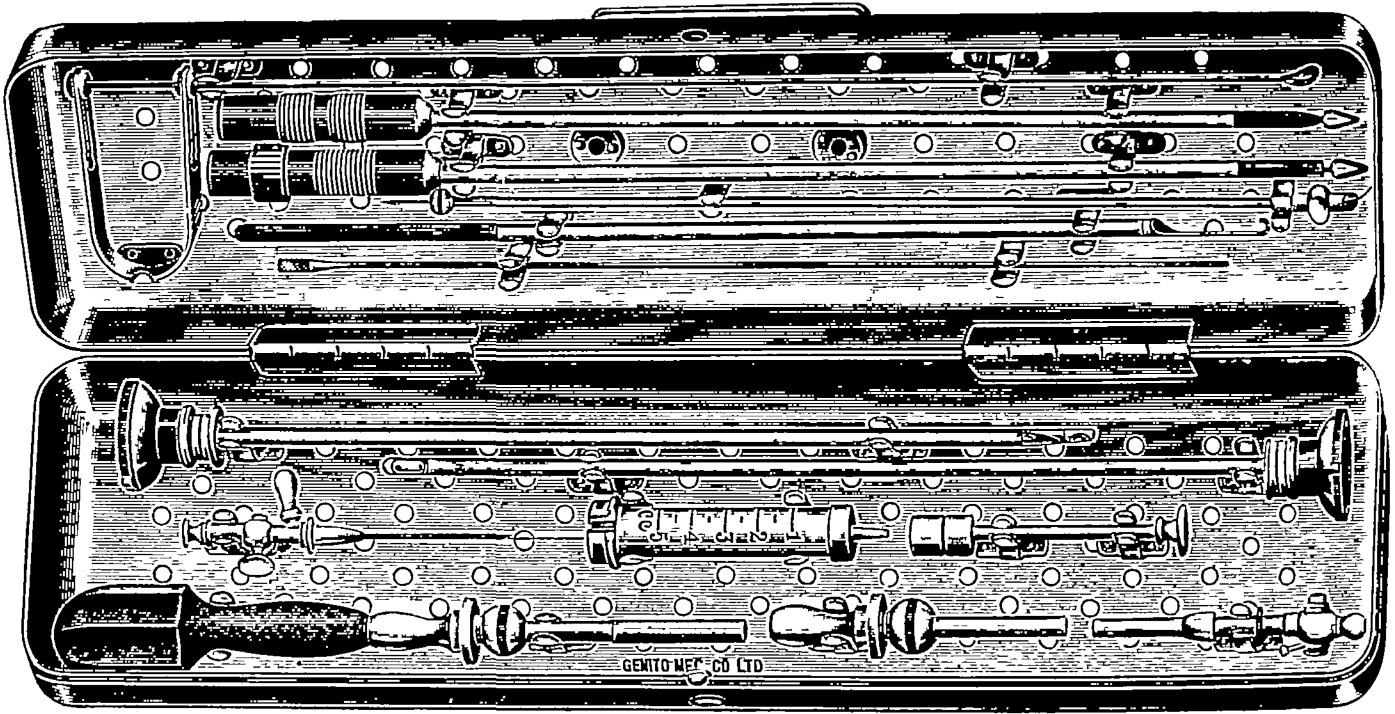


FIG 9 15 —Double puncture thoracoscope

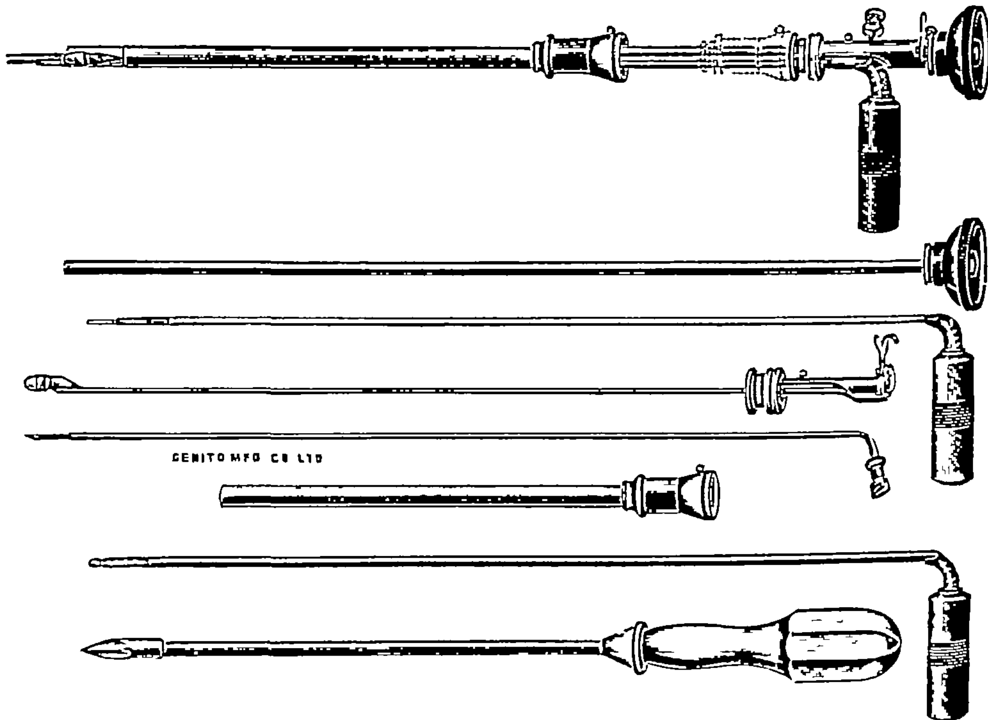


FIG 9 16 —Single puncture thoracoscope

field of intrapleural manœuvre that is attainable (Fig 9 15) These factors and the availability of either cannula for vision or for introducing the cutting instrument perhaps makes the division of multiple adhesions safer the operator too can often determine more

readily whether he can divide safely because both the front and the back of the bands can be seen Apart from the need to employ two small puncture holes the apparatus is simpler than the single puncture instrument and less prone to break down because of this If bleeding follows the division of an adhesion by the single puncture instrument the lamp is more readily clouded by blood a disadvantage easier to avoid with the double instrument technique

Technique of adhesion division In most instances the adhesions are situated posteriorly and a pre-operative estimate of their size and position is attempted by a study of the radiographs and by screening But the true nature of the bands and an opinion as to divisibility can be made only at the thoracoscopic examination Usually the patient lies on the normal side with the head of the table raised and pillows arranged in such a way

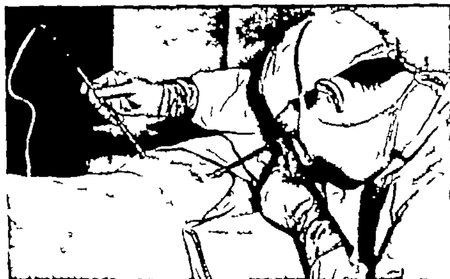


FIG 9-17 —Thoracoscopy by the two cannula method
The patient is lying on the left side

that the uppermost side of the chest is convex The site selected for the puncture varies with each pneumothorax but usually the first cannula should be introduced in the sixth intercostal space posteriorly just behind the angle of the scapula The skin and pleura having been anaesthetized by the injection of 2 per cent procaine an artificial pneumothorax needle is introduced to confirm the presence of an adequate pneumothorax space free from adhesions these or a too distended lung can be detected readily when the stilette of a re-fill needle has been passed beyond the opening at the needle end

Into the space a cannula mounted on a trocar is introduced and the telescope then replaces the trocar if this has been previously warmed in hot water and rapidly wiped dry fogging will not develop on the lamp if the view is misty it will clear after a few moments when the normal warmth of the pleura has ceased to act Other causes of a hazy view are blood on the lens or because the telescope is touching adhesions or lung itself

A complete survey of the pneumothorax should be made before the second cannula is introduced and the surgeon will decide on the possibility of adhesion division It is so unwise to leave the diseased area still unrelaxed after ineffective partial adhesion division that careful study is well repaid the aim is to divide completely adhesions that are preventing a selective collapse at one session if possible as this decreases the risk of post

operative complications. But occasionally a second or third attempt may be required to provide a good result.

Contra-indication to adhesion section. If the contra-indications to pneumothorax therapy have been observed the patient will not have reached the operating table unless a good pneumothorax will follow division of any restricting adhesions. During the thoracoscopic examination the operator may decide that pneumothorax therapy is unwise and should be abandoned. If the task of mobilizing the lung involves the risk of lung tissue being cauterized, this should not be attempted, for such a misfortune carries a high empyema incidence. Nor should too extensive systems of adhesions be attacked, as their incomplete division increases the post-operative incidence of effusions. Short adhesions to peripherally placed cavities should not be divided as the blood supply to the cavity wall may be through such bands, especially when they are very vascular, and the cavity may rupture later after necrosis of its wall. The presence of actual tubercles on the adhesion or the parietal and visceral pleura are contra-indications to adhesion section.

Local areas of emphysema in the apex of the lung do not contra-indicate adhesion section; in fact the division of bands to these areas of over-distension is a valuable preventive of a spontaneous pneumothorax into the artificially produced one. But if emphysematous bullae are seen over a wide area of lung the pneumothorax should be abandoned and other forms of treatment considered.

The severance of adhesions. If the adhesions are conveniently placed, sufficiently long and surgically accessible, the section should be made as close to the chest wall as possible and it is a good practice to enucleate the bands by actually dividing the parietal pleura and carrying the line of section well into the endothoracic fascia; enucleation need not be used for long thin adhesions obviously free from lung tissue. Enucleation of adhesions greatly diminishes the danger of dividing lung tissue that may have been pulled out into the course of the band but it is more painful than division across the body of the adhesions. If the area to be cauterized is extensive, pain can be diminished by injecting procaine into the base of the adhesions through the special long needle provided in the thoracoscopy set.

The cutting agent employed is the cautery and not the diathermy current; the latter coagulates a wide area of tissue and the range of necrosis so produced may run on into lung tissue which might slough to produce a fistula and consequent empyema. Bleeding from the adhesion on the chest wall side can be checked by applying diathermy but usually cautery at dull red heat suffices and causes less pain to the patient.

Adhesions are divided slowly with the cautery point at dull red heat; if the point is left too long against the adhesion it becomes covered with coagulated tissue that transmits heat badly and the actual division is best achieved by repeated applications of the knife along the line of division; during the course of dividing broad adhesions the cautery point must be removed from time to time and cleaned outside the chest.

Before apical adhesions are divided inspection of the dispositions of the subclavian vein and artery and of the azygos vein on the right must be made before the bands are sectioned. In the literature occasional disasters of haemorrhage have been recorded following injury to the subclavian vein. Because of the occasional risk of severe bleeding, a standard thoracotomy set of instruments should be laid out in preparation for rapid action which may be necessary.

Apical adhesions can be more readily studied and divided if the patient is raised to a sitting-up position, with appropriate rotation of the chest so that the lung can fall away from the area of the chest wall to which the band is attached.

At the end of the adhesion section the lung is allowed to re-expand partially by allowing

air to escape during a few breaths by removing a finger from the end of the cannula during expiration. The puncture wound is then closed by a single suture and a firm strapping applied over the area

Post-operatively the patient should be propped up preferably lying towards the operated side A radiograph is taken 12 hours after the thoracoscopy and the pneumo thorax adjusted according to the radiological findings Cough should be checked as much as possible for the first 24 hours unless atelectasis has developed and for this reason the patient should be nursed in isolation and all unnecessary talking and moving avoided The clinical condition is frequently re-assessed so that bleeding can be readily diagnosed if of any severity

Post-operative complications A little subcutaneous surgical emphysema around the wound is not uncommon and is of no significance it may be more widespread if coughing is troublesome The emphysema is not in itself dangerous but if extensive it indicates the risk of full re-expansion of the lung with loss of the pneumothorax It is an indication for immediate radiographic examination so that air can be let in by the pneumothorax apparatus if the space has apparently been lost or even dangerously decreased in size Full re-expansion may require the whole process of re-induction of a pneumothorax to be carried out Post-operative effusions should be aspirated when seen on the X ray film for if neglected they may lead to loss of the pneumothorax which may creep out as the result of an early basal adherence to the diaphragm and chest wall If the effusion recurs rapidly this may indicate the start of a tuberculous empyema If tubercle bacilli and pus cells are found in such effusions every effort should be made to obtain rapid re-expansion of the lung as other methods of treatment will often enable the patient to escape the possible horrors of a total thoracoplasty or a pleuro pneumonectomy if a total empyema develops

If the lung remains atelectatic not only should the fluid be aspirated daily if need be but bronchoscopic aspiration should be employed to make sure there is no bronchial occlusion from muco purulent plugs Persistent atelectasis developing after thoracoscopy is a major catastrophe often indicating that the selection of the patient for pneumothorax and adhesion section was faulty It is rarely seen in modern practice

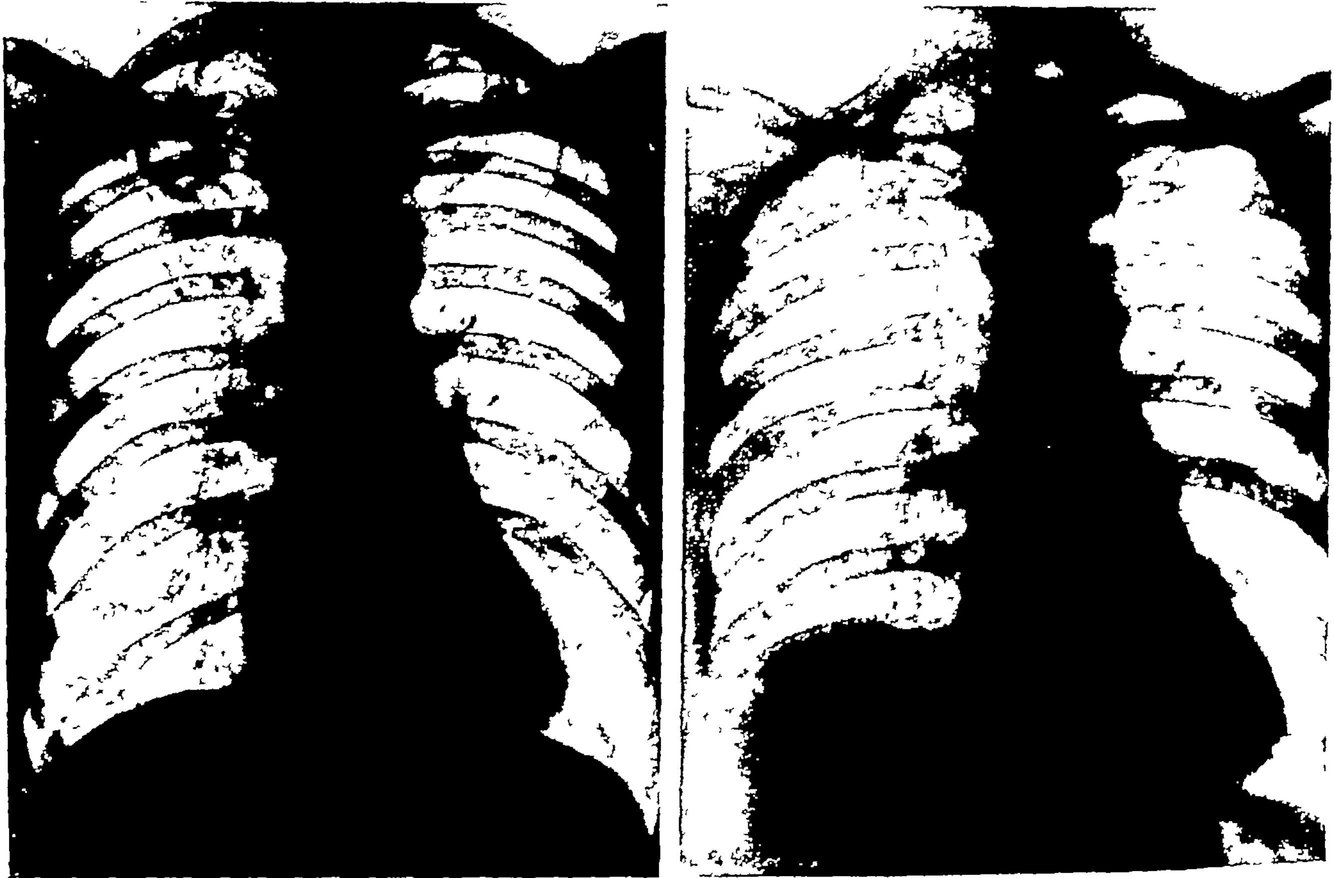
OPEN PNEUMOLYSIS

From time to time minor waves of enthusiasm for the operation of open pneumolysis through a free thoracotomy incision are apparent in the surgical literature The indications in such series have notably been those occasions on which selective collapse is essential for saving the patient s life and when thoracoscopy has revealed massive vascular bands quite indivisible by the method of closed pneumolysis It is not possible to speak with enthu siasm of this operation because even in the most expert hands there have been a distressingly high proportion of bad results the chief complication being persistent post-operative effusions and empyemata In a very few patients the indications for this operation might exist but it is not a method that can be recommended

PHRENIC NERVE INTERRUPTION

The great decrease in the use of this minor or auxiliary method of collapse therapy followed dissatisfaction with the results of its use and more especially because a permanent

diaphragmatic paralysis may be a grave disability in patients who develop serious lesions in the other lung or who require a thoracoplasty on the same side The objections, which may have been over-emphasized, to a phrenic paralysis performed on a patient who may later have to undergo thoracoplasty are based on the fear that atelectasis is more likely to develop in the lower lobe because of the lack of an adequate ventilation, the result of a non-functioning diaphragm These objections are not based on adequate statistics in 98 patients at Yardley Green Hospital, in whom a study of pre-operative states was related to post-operative complications, only seven of the patients who underwent upper partial



(a) (b)

Fig 9 18

(a) Thick-walled cavity in the right upper lobe in a man aged 62 with positive sputum Because of his age thoracoplasty seemed unwise (Dr A Brian Taylor's patient)

(b) The cavity illustrated in Fig 9 18 (a) disappeared within two weeks after a right phrenic nerve interruption

thoracoplasty in the presence of a paralysed diaphragm showed evidence of defective aeration of the base of the lung at any time after operation, and this number was equalled in those with a freely moving diaphragm

A more physiological objection to phrenic paralysis is the loss of function in the lower lobe after the operation in modern thoracoplasty only the upper ribs are sacrificed to leave a normal functioning lower lobe and this ideal is seriously interfered with by a hit-and-miss phrenicectomy done previously in the hope (occasionally fulfilled) that an upper lobe lesion would be benefited

The statistical assessment of the benefits that follow phrenic nerve interruption is difficult because it is rarely employed as the sole method of treatment, being combined normally with other measures and often in association with an artificial pneumothorax

Of its occasional assistance in the treatment of individual patients there can be no doubt and every tuberculosis physician can point to odd patients where lives have been saved by phrenic nerve interruption But as a treatment of cavities wherever situated it has proved disappointing when used alone combined with artificial pneumothorax or pneumo peritoneum it has proved its value It does not usually influence thick walled chronic cavities and is contra indicated in patients with upper lobe cavities associated with bronchial disease detected either bronchoscopically or by the typical radiological appearances of that lesion It should not be used in dyspnoeic patients especially in the older age group as it may cause serious respiratory embarrassment by sacrificing the function of useful respiratory tissue

In phrenic nerve interruption the paralysis should be of the temporary type until its beneficent action has been proved by the results in the individual patient when a conversion to a permanent paralysis may be justified but as commonly done the phrenic crush is followed in over 25 per cent of patients by permanent diaphragmatic paralysis To lessen the risks of permanent paralysis after the crush operation the nerve should not be lifted from its sheath and should be crushed with reasonable gentleness so that nerve regeneration will follow

Chief indications for phrenic paralysis

(i) For cavities when other measures are contra indicated
(ii) Combined with pneumo-peritoneum in the treatment of
  (*a*) lower lobe cavities
  (*b*) upper lobe lesions
(iii) Combined with an artificial pneumothorax or at the conclusion of pneumothorax therapy in a few instances
(iv) After resection of a lobe or lung for tuberculous disease
(v) Occasionally for scattered exudative disease which is responding to bed rest and where artificial pneumothorax is contra indicated or unattainable because of pleural symphysis
(vi) For persistent pain due to chronic diaphragmatic pleurisy

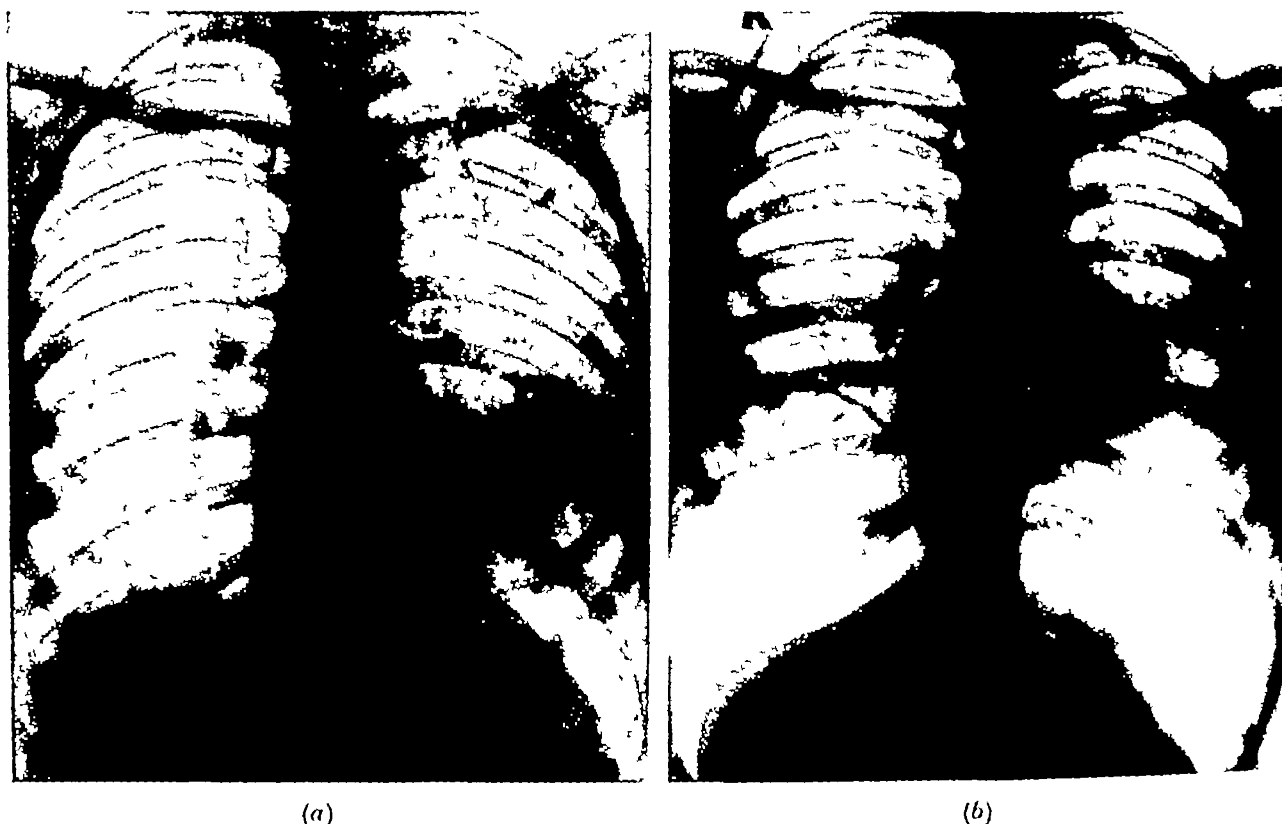
Phrenic interruption alone and combined with pneumo-peritoneum or artificial pneumothorax for lower lobe cavities The difficulty of treating lower lobe cavities is emphasized by the list of procedures employed for their treatment and by the conflicting reports published from different clinics on the results of one or another form of surgical treatment The circular nature of the cavity its periodic inflation and deflation the radiological appearances and the bronchoscopic detections of tuberculous endobronchitis leave no doubt as to the presence of tuberculous tissue in the draining bronchus of these cavities and this has been confirmed on many occasions by the study of excised lobes The alteration of the mechanics of the cavity can be achieved more readily in the lower than the upper lobe because it is more mobile Occlusion of the cavity bronchus may be obtained by phrenic interruption alone (Fig 9 18) by artificial pneumothorax with phrenic paralysis and occasionally by the use of an effective pneumo peritoneum and phrenic nerve crush (Fig 9 19)

Phrenic nerve interruption with pneumo-peritoneum is indicated when an upper lobe cavity suitable in itself for thoracoplasty is complicated by exudative lower lobe disease such a condition is employed as a measure preparatory to the thoracoplasty and may lead to the closure of the upper lobe cavity

The operation for interruption of the phrenic nerve

This is performed under local anaesthesia with the patient lying supine on the operating table, with a small sandbag under the shoulders and with the head and neck rotated to the opposite side. A small horizontal incision, 2.5 cm in length, is made in the posterior triangle of the neck, two fingers' breadth above the clavicle and slightly overlapping the posterior margin of the sterno-mastoid.

The skin and platysma are divided, the remainder of the operation from that stage being executed by blunt dissection, using a fine pair of artery forceps. The posterior border of the sterno-mastoid is fully exposed and held medially by a small illuminated



(*a*) (*b*)

Fig. 9.19

(*a*) Large left upper lobe cavity; exudative disease in left lower lobe.
A left phrenic nerve interruption and pneumo-peritoneum was employed as a preparation for upper thoracoplasty.

(*b*) The same patient as illustrated in Fig. 9.19 (*a*).
The cavity has closed and the pneumonic infiltration of the left lower lobe is much improved.

retractor; in the posterior margin of the wound the external jugular vein is demonstrated and retracted laterally. The assistant exerts an upward traction on the sterno-mastoid while the operator clears the underlying space by blunt dissection. The scalenus anticus muscle covered by a fibro-fatty layer is cleared thoroughly and the phrenic nerve found lying on its anterior surface proceeding in an inward and downward direction just under the sheath of the muscle. In the inferior part of the wound care is taken to avoid damaging the plexus of veins, while more superiorly the transverse cervical artery and its accompanying vein will be clearly visible. At the medial end of the wound the internal jugular vein may be seen; slightly external and deep to it lies the cervical sympathetic nerve at the innermost edge of the scalenus anticus. It is quite different in appearance from the phrenic nerve. At the posterior end of the wound the brachial plexus will be seen emerging

deep to the scalenus anticus In many patients a careful search will reveal a small accessory nerve proceeding from the front of the plexus and curving medially to join the main phrenic nerve usually at the level of the left subclavian vein within the thorax

The phrenic nerve and any accessory seen is crushed the patient characteristically feeling pain in the shoulder and the upward lift of the diaphragm The retractors are removed, the platysma approximated by a few interrupted 0000 catgut sutures and the skin closed with Michel clips which are removed three days after the operation

The operation of phrenic avulsion has been abandoned when it was in extensive use occasional disasters followed the pulling out of the phrenic nerve Those were due to intrathoracic bleeding In the unusual event of permanent phrenic nerve interruption being indicated the phrenic nerve should be divided in the neck and a very special search made for the accessory nerve

THORACOPLASTY

The ideal thoracoplasty provides a permanent selective collapse with minimal deformity and the preservation of as much functioning lung as possible This aim contrasts strongly with the achievements of the earliest ventures in thoracoplasty Its chief indication is in



(a) *(b)*

Fig 0-20

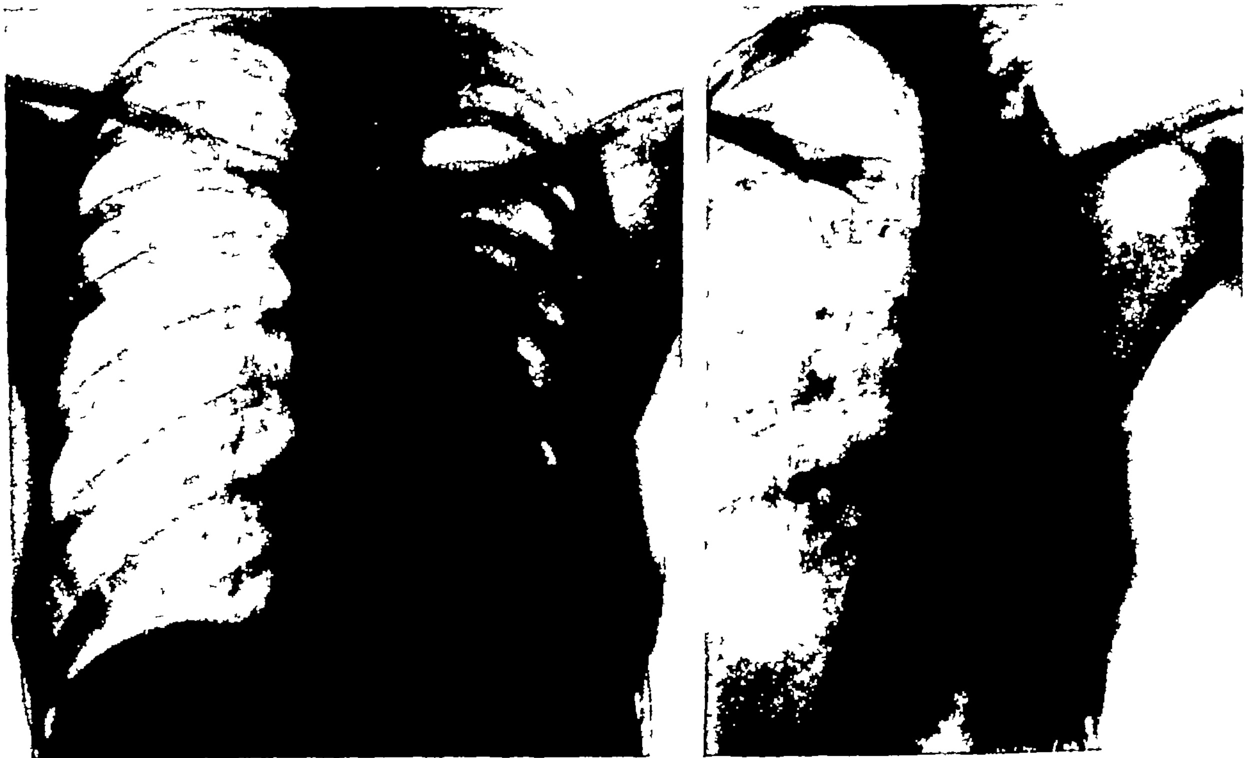
(a) A supraclavicular cavity in a woman aged 30 shown by tomography
(b) The cavity has been closed by a one-stage small thoracoplasty involving resection of the first three ribs and part of the fourth

The sputum has remained negative for five years

the control of upper lobe cavities It is no longer accepted that before considering the operation an attempt to close the cavity by the induction of artificial pneumothorax should have been made even less favoured is the appeal to a preliminary hit-or-miss phrenic nerve interruption Each collapse operation has the limitation of its own indication, "primary" thoracoplasty is often used for the treatment of upper lobe cavities without preliminary attempts at closure by artificial pneumothorax or phrenic paralysis Thoracoplasty is applied to many patients in whom an artificial pneumothorax has been ineffective, or abandoned, at an early date If an ineffective pneumothorax is maintained too long, the ultimate thoracoplasty may have to be extensive An artificial pneumothorax employed for an upper lobe cavity without success may lead to collapse of a previously sound lower lobe, often with pleural effusion, if this pneumothorax is abandoned too late the substituted thoracoplasty may have to be extensive to cover the whole lung Moreover, physiological studies show that a pneumothorax abandoned because of pleural effusion permanently decreases the respiratory capacity of the lower lobe because of the impaired function of the diaphragm and ribs and an adherent pleura

Partial or total thoracoplasty

The extensive unilateral fibrocaseous disease with gross distortion of the mediastinum and extreme falling-in of the over-lying ribs which provided the earliest subjects for thoraco-



(*a*) (*b*)

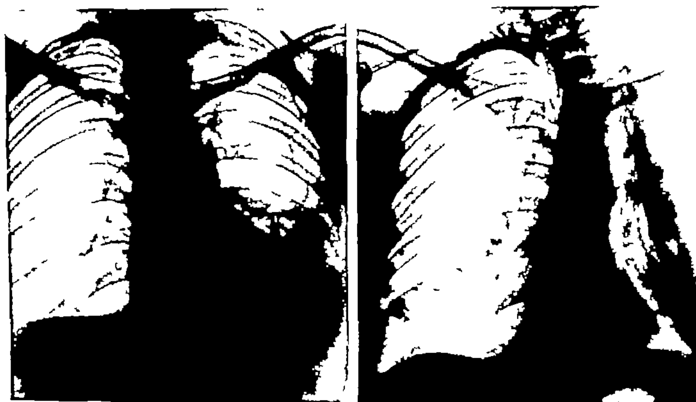
Fig 9 21

(*a*) A woman aged 32 Large upper lobe cavity with extensive disease in the remainder of the lung This would now be regarded as an indication for left pneumonectomy

(*b*) A three stage thoracoplasty has been performed with sputum conversion

plasty in the brilliant pioneer work of Brauer, Sauerbach, Morriston Davies and Alexander are rarely seen today they represented survivors of advanced lung disease who by their natural resistance had lived long enough to win final relief by a nature assisting ten-rib thoracoplasty

Earlier diagnosis bed rest antibiotic therapy and efficient artificial pneumothorax therapy now cure many patients before this stage and the aim in thoracoplasty is to cure or relieve by a partial upper operation A total thoracoplasty indicates that the early management of upper lobe cavities has failed or that it is required as the drastic end treatment of the pneumothorax failures such as the pyo-pneumothorax or for the closure of huge cavities that can only be collapsed by wide rib resection Most of these extensive lesions are now treated by lung resection but excision may be contra indicated because of the state of the other lung In the patient whose radiographs are shown in Fig 9·21 a three-stage thoracoplasty was effective in getting rid of sputum and the patient was well



(a) (b)

Fig 9·22

(a) A woman aged 20 Two huge cavities in left lung.
(b) Two years after three-stage thoracoplasty
Sputum negative. The operation was done before pneumonectomy had established itself.

three years later Even for most extensive cavitary disease a less than total thoracoplasty may yield excellent results (Fig 9·22) The cavities shown in the left lung would now be resected but a three-stage thoracoplasty closed them and rendered the sputum negative to culture examinations

Extensive thoracoplasty however is rarely in use and lung resection normally provides better results for widely destroyed functionless lungs The chief place for rib resection is the closure of upper lobe cavities by a limited partial thoracoplasty *requiring removal of* portions of the first seven ribs combined with an extrafascial apicolysis or as a means of decreasing the size of the hemithorax after upper lobectomy or pneumonectomy The thoracoplasty may sometimes only involve resection of portions of the upper five ribs

Primary thoracoplasty

The clinic with the highest incidence of perfect pneumothoraces has a high proportion of primary thoracoplasties because the patients selected for the latter operation are those in whom a perfect pneumothorax is unattainable

When the lesion under consideration is one that demands permanent collapse, and the other lung is in a satisfactory condition with the patient suitable in other respects for major surgery, a primary thoracoplasty is indicated The patients fall into five groups

(*i*) Extensive fibro-cavernous disease
(*ii*) Truly apical cavities
(*iii*) Tuberculous bronchial diseases associated with a cavity in an area of atelectasis the cavity is usually "tension" in type
(*iv*) Patients over the age of 40 in whom an artificial pneumothorax is considered inadvisable largely on the age basis
(*v*) Patients with apical cavities who have had a previous pleural effusion

An increasing number of patients with these lesions are being treated by resection of the involved lung tissue

Thoracoplasty as a primary measure will often save time, avoid the complication of pleural effusion and atelectasis and provide a permanent collapse of a lobe that could never return to normal after pneumothorax therapy and at the same time will usually close the cavity permanently

Thoracoplasty in bilateral disease

The ideal patient for thoracoplasty has no disease in the contra-lateral lung; but were the selection of patients confined to this group, the number of cavities closed by thoracoplasty would be small indeed and in over 50 per cent of those submitted to operation in this country there is disease in the "good" lung The closure of the cavity in the bad side will allow minimal or moderate infiltrations in the other lung to heal under sanatorium regime aided perhaps by antibiotic therapy In some patients the lung on the side opposite to the proposed thoracoplasty may require temporary artificial pneumothorax relaxation and if the pneumothorax is shallow the operation can be performed safely.

Bilateral thoracoplasty has a small place in the treatment of suitable bilateral upper lobe cavities, it is a serious intervention and the results are not always satisfactory. In an even smaller group the patient may be submitted to a thoracoplasty on one side and an extrapleural artificial pneumothorax on the other

Thoracoplasty operations

Thoracoplasty having been decided upon, the type of operation selected depends on the state of the patient and of the lesion to be treated There are many different types of operation in use throughout the world and the choice would seem to be bewildering, but in practice the principles governing the different operations are standard

Multiple stages The operation is done in stages and extensive resections at one session are no longer practised, the standard upper partial thoracoplasty in Great Britain being done in two or three stages This staging reduces the post-operative shock, the risks of paradoxical respiration and the incidence of lower lobe collapse A typical upper thoracoplasty usually involves resection at the first stage of the whole of the first three ribs from the neck of the rib to the costal cartilages, at the second stage large segments of the fourth and fifth ribs are resected It is at this stage that paradoxical respiration most commonly develops and in

(a)

(b)



(c)

FIG. 9–3

(a) A woman aged 35. A pneumo-peritoneum has failed to influence a left upper lobe cavity.
There is also disease below the right clavicle. A left upper thoracoplasty was decided upon.

(b) An upper thoracoplasty with apicolysis has closed the large upper lobe cavity.
But a year later there is a considerable cavity of the right upper lobe; the vital capacity was only 800 c.c. and an extrapleural pneumothorax was considered to be the only possible treatment; artificial pneumothorax could not be established.

(c) Six months after right extrapleural pneumothorax.
The [illegible] is closed and the [illegible] is negative.

patients with a mobile mediastinum and a tendency to paradoxical respiration the resection is often stopped at this stage, but if the danger of this seems minimal the resection of a smaller portion of the sixth and seventh ribs is completed. The interval between the stages is usually two weeks.

The extent of the thoracoplasty. This is regulated chiefly by the radiological extent of the disease; it is usually necessary to resect one rib lower than the most inferior area of the disease and this is judged in relation to the posterior ends of the ribs. In practice the actual resection often needs to proceed only to the sixth rib, but the projecting seventh rib may impede the settling-in of the scapula, the angle of which tends to ride uncomfortably unless its posterior half is removed. The extent of the resection is not always accurately prejudged by a study of the pre-operative X-ray film because the extrafascial apicolysis may drop the level of the disease to a considerable degree. Quite exceptionally for cavities sited above the clavicle a really small resection will suffice (see Fig. 9.20). At the time of writing, however, there is an increasing tendency to combine an extrafascial apicolysis with complete resection of the first three ribs and remove small posterior segments of the fourth and fifth ribs. Such a modified thoracoplasty may be executed at one stage in some patients and the collapse maintained by an extrafascial pneumothorax for three months.

Resection of the posterior ends of the ribs. It is essential to resect the ribs to the level of the costo-transverse joint and this means the rib should be divided through its neck or the neck and head may be completely removed. Unless the transverse processes are removed there seems to be little point in removing the neck and head of the rib and transversectomy has become increasingly unpopular because it adds to the risk of spinal scoliosis. If, however, the ribs are not meticulously resected to the level of the transverse process the relaxation and mobilization of the posterior part of the thorax is incomplete and the collapse obtained inadequate, as the regenerated ribs will become anchored to the jutting-out rib segments to mar a well-shaped thoracoplasty.

The need for vertical as well as lateral relaxation. Semb's extrafascial apicolysis. When the ribs have been resected the lateral collapse obtained will be striking, but the apex of the pleural dome is still held up above by strong muscular and fibrous bands; since thoracoplasty aims to produce a selective collapse of the diseased area this superior fixation of the pleura interferes greatly with complete vertical relaxation. The ideal thoracoplasty in this respect resembles the ideal artificial pneumothorax, so that the apex of the lung falls well below the level of the clavicle to provide concentric relaxation of the upper lobe. When a pneumothorax is ineffective for upper lobe lesions because of apical and mediastinal adhesions, not divisible at thoracoscopy, the substituted thoracoplasty may also fail if the same tension bands persist under the resected ribs. To overcome this deficiency Semb (1935) introduced his extrafascial apicolysis to supplement the thoracoplasty. The first attempt to correct this defect in upper thoracoplasty by performing an extrapleural apicolysis in the plane of the endothoracic fascia had been made by Holst (1935), but re-expansion of the lung is more likely after this operation and the more effective extrafascial apicolysis of Semb has largely replaced it. The free use of Semb's procedure has led to the closure of upper lobe cavities in about 85 per cent of instances.

The production of minimal deformity. Deformity will not be obvious if good physiotherapy is available from the outset; even with a ten-rib thoracoplasty (now rarely performed) the deformity will not be noticed when the patient is clothed. Naturally the shape of the chest is altered and there is always anterior flattening, but the greatest deformity is caused by spinal scoliosis and this can be minimized. The correct posture after the

operation requires constant attention most readily achieved by the patient's use of a mirror at the end of the bed and by the careful re-education of arm neck and spinal muscles by the physiotherapist



FIG 9 24 —The use of the mirror after thoracoplasty to prevent the development of scoliosis.

The operation of thoracoplasty

Pre-operative treatment The general hygiene and rest measures of a sanatorium life are invaluable in the pre-operative phase and are associated with the usual dietetic fluid electrolyte and blood restoration features common to any major thoracic operation The value of streptomycin given pre-operatively requires consideration Its rigorous exclusion as a preparatory treatment would prevent many patients from reaching the stage at which thoracoplasty could be used, but in the good risk thoracoplasty patients with chronic disease streptomycin should not be used In the carefully controlled Medical Research Council experiment (1951) its pre-operative use was not really effective but as a weapon against post-operative complications such as re-activations new infiltration and wound infection its value was undeniable Our own practice is to avoid using it as a prophylactic measure to cover the operation unless as part of the continuation of a programme instituted previously for the general care of the tuberculous disease we do not hesitate to use it for the management of any post-operative complication likely to benefit from it

Anaesthesia (*a*) *Local anaesthesia* Local anaesthesia is popular in some clinics the advantages over general anaesthesia being the decrease in blood loss and surgical trauma the persistence of a cough reflex the maintenance of quiet regular respiration and the avoidance of a lung irritant or of deep narcosis which may delay the return of conscious coughing when the patient is back in bed The early post-operative co-operation of the patient not only eases the post-operative nursing care but helps in the prevention of atelectasis or dissemination of the disease In the pre-operative phase the advantages of local anaesthesia are explained to the patient and with adequate premedication (omnopon and scopolamine) his co-operation in the theatre is usually good The local regional anaesthesia should be produced by an anaesthetist skilled in this work and it is unwise for the surgeon to be responsible for this part of the operation it is in itself a tiring and

lengthy operation requiring a most meticulous technique, moreover in occasional patients who become unco-operative and frightened during the operation the anaesthetist may be required to provide supplementary anaesthesia

For the safe and easy performance of an upper thoracoplasty with apicolysis the brachial plexus, the upper five or six intercostal nerves and the line of the skin and muscle incisions must be blocked. the nerve block may be intercostal or paravertebral for the brachial plexus and the intercostal nerves a solution of 1 in 400 procaine with 1 in 1,000 amethocaine is used, amounts up to 50–70 c c being a safe total dose. The skin and muscles are infiltrated with a weaker solution of 1 in 400 procaine with 1 3,000 amethocaine, a total amount of up to 200 c c. being employed. Adrenalin three minims of a 1 in 1,000 solution are added to each of the flasks containing the procaine solution to help haemostasis (Joan Millar, 1948)

At the second and third stage the brachial plexus block is not necessary, otherwise the same type of nerve block and infiltration is used

Complications of local anaesthesia The commonest complications are restlessness and bouts of coughing, if the latter is troublesome every inducement should be made to persuade the patient to cough up irritating pus or mucus, if the restlessness is severe the safest supplementary anaesthesia is often the cautious administration of a little chloroform on a mask

A rare complication of local anaesthesia may be the development of severe convulsions, due to overdosage probably of amethocaine, if the amounts listed above are not exceeded they should not occur Their treatment is by immediate incision along the injected line to allow the fluid to escape and be mopped out with warm saline pads and the administration of intravenous pentothal. During the injection of the local procaine into the intercostal spaces a small pneumothorax may be induced inadvertently The prompt recognition and treatment of this by aspiration of the air is necessary

(*b*) *General anaesthesia.* This is satisfactory for many thoracoplasty operations and is used in nervous patients or those with skin infections or sinuses that may be complications of a pyo-pneumothorax for which thoracoplasty is to be undertaken Especially careful pre-operative drainage and post-operative bronchoscopic suction is required, when general anaesthesia is used for patients with much sputum

The induction is by pentothal and curare may be used to produce good muscular relaxation, the lung being artificially inflated this combination is probably preferable to the use of pentothal and ether or cyclopropane Nitrous oxide should not be used, as it does not produce satisfactory anaesthesia without risks of anoxaemia, and its use may cause exaggerated respiratory movements which increase the tendency to paradoxical breathing If there is sputum present intratracheal intubation is advisable so that suction can be applied promptly

The position on the table. An exact lateral position with no twisting of the spine is essential for efficient operating A small pad is placed underneath the axilla and the chest piece of the table and the pelvic and buttocks props must be snugly in position to prevent any change of position while the scapula is being retracted; the underneath arm must be pulled well through beneath the patient so that the tendency to fall towards a prone position will be discouraged (see Fig 4 7, Chap 4)

The incision. *First stage* For this stage a large peri-scapular incision is used in this country, it commences high up at the highest point of the transverse sweep of the trapezius muscle, as this slopes from the neck to the scapula, unless this muscle is divided really high, scapular retraction is inadequate and unnecessarily strong and trauma-

tizing The skin incision begins 1¼ inches (4 cm) lateral to the spinous process and runs parallel to the scapula until it turns forward 1½ inches below the angle of the scapula to reach the mid axillary line The justification for this large incision is the good access it provides for the later stages of the operation and because it greatly eases the difficulty of scapular retraction The interscapular muscles are then divided the approach to them is made through the area of the auscultatory triangle which is opened down to the loose areolar tissue overlying the ribs in this area When this space has been opened the assistant slides one finger beneath the overlying trapezius and rhomboid muscles on his side the surgeon doing the same on the other side of the wound the muscles held tautly upwards are divided by the diathermy cutting knife cut vessels being picked up in artery forceps

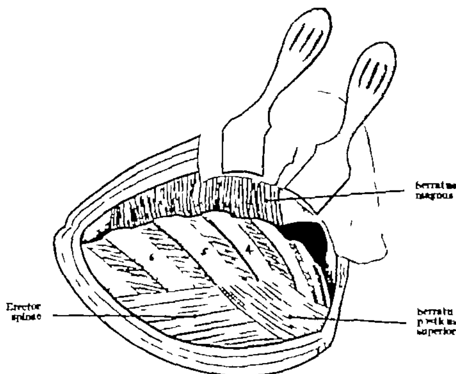


Fig 9·25 —Drawing of exposed ribs. But before division of the serratus magnus.

as the incision proceeds When the division of the muscle has proceeded nearly up to the neck the erector spinae muscle is seen clearly beneath

In the same incision the latissimus dorsi muscle is divided in the anterior edge of the wound This muscle carries large blood vessels on its surface which can be picked up on each side with forceps before the diathermy knife proceeds with their section

Haemostasis is secured by ligating the large vessels and applying the diathermy point to the others The scapula is held in a large moist saline pad and lifted well off the chest wall by the use of a scapula retractor the loose areolar tissue binding it to the chest wall is divided by the scalpel until the digitations of the serratus magnus muscles are seen passing from the ribs to the scapula The serratus magnus muscle is then cut as close to the chest wall as possible by the diathermy knife this dissection should start at the upper border of the second digitation of the muscle this is the largest digitation and is separated from the first one by a small gap into which a finger can be inserted and hooked beneath the muscle band The first five digitations are severed and in the course of this the long thoracic artery and vein will be secured and divided as high up as possible The first

digitation should be cut through slowly and carefully by long lobectomy scissors with the brachial plexus and axillary vessels kept well in view as they lie on its anterior surface, when this band has been freely divided the neuro-vascular bundle is seen lying above the first rib in the axilla

The serratus posticus superior muscle is partially resected from the chest wall to expose clearly the posterior thirds of the upper four ribs

The resection of the ribs Counting from above downwards the third rib is identified and its periosteum incised from the edge of the erector spinae muscle up to the costal cartilage by the diathermy knife The periosteal cuff is then elevated along the upper border first by Tudor Edwards's curved rib raspatory, the greatest care being taken to clear the upper edge clearly and fully with the instrument working from behind forwards, the lower edge is then cleared by working in the opposite direction, the final sub-periosteal clearance being effected by the use of Doyen's raspatory The outer edge of the erector spinae muscle is then divided with the diathermy point and the muscle fully retracted posteriorly by the use of two posterior end retractors The superior and inferior surface of the posterior ends of the ribs are then carefully cleared of their muscles, including slips from the erector spinae and the pleura and periosteum in front of the neck of the rib meticulously pushed away from the bone in the costo-vertebral gutter this is important as the pleura is easily damaged in this area The rib is then divided through its neck after the costo-transverse articulation has been opened, this may be done by Price Thomas's method of using the tips of his posterior end-rib shears to cut through the articulation and then sliding them down to cut the neck of the rib, an alternative method is to divide the rib in front of the articulation The small posterior ends are then grasped in special bone-holding forceps, the costo-transverse articulation being opened with Semb's disarticulating instrument and the neck and head of the rib removed by the use of posterior end punch forceps or rongeurs The front of the rib is then divided at the costo-chondral junction

Some surgeons prefer to resect only half the third rib at this first stage to decrease the risks of paradoxical breathing but this is unusual after a first stage in which the whole of the first three ribs are resected

When the third rib has been resected a gauze swab is placed in its bed to check oozing of blood and to apply some firm pressure to the mobile lung and pleura

The second rib is then resected It lies far more horizontally than the third and after its periosteum has been divided its under surface is rapidly cleared by the use of Price Thomas's broad flat periosteal elevator, the whole of the under surface should be cleared before the upper edge is cleared, for after this has been done the underlying pleura is well away from the rib and the upper surface is easily freed of its periosteum and attached muscle The rib is resected from its transverse process to its costal cartilage

The resection of the first rib is conducted under full vision if the scapula has been fully mobilized off the chest wall and the serratus magnus (first digitation) has been divided As in the case of the second rib the under surface is cleared first to the neck of the rib across which the first thoracic nerve is seen joining the seventh cervical nerve, this cord is clearly seen and avoided The periosteum of the upper surface of the rib is pushed off the bone with Price Thomas's long curved periosteal elevator the scalenus anticus may be cleared from the bone at this stage or divided later by sharp dissection after the posterior end of the rib has been divided and held downwards in bone-holding forceps the anterior section of the rib should be at the costal cartilage junction The subclavian vessels are protected with a finger of one hand while the periosteum in their vicinity is being cleared

The extrafascial apicolysis. The essential feature of Semb's operation is the section

of all muscular slips and tendinous bands that pass down from the neck and thoracic wall to the fascia overlying the apex of the pleura It is not a pneumolysis carried out in the extrapleural plane as is done in the operation of extrapleural artificial pneumothorax the extrafascial mobilization allows the upper part of the lung to be relaxed vertically as well as laterally The associated section of the periosteal envelopes posteriorly is followed by regeneration of the resected ribs in a position lower than their normal site and thus helps in providing a permanent decrease in size of the artificially created Semb s space

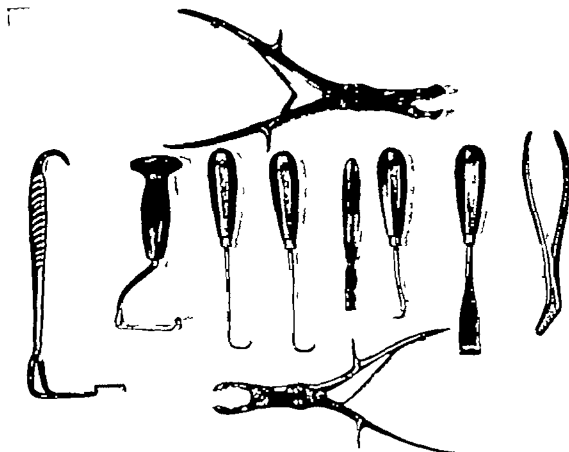


Fig 9-26.—Instruments used in thoracoplasty

Price Thomas angled rib shears.

Scapula retractors ( ). Erector spinae retractors ( ) Lambotte raspatory Small curved raspatory Long curved raspatory Bone-holding forceps.

Rongeurs for removal of back ends of rib.

The fibrous envelope of the brachial plexus is freely incised and the lowest cord is gently retracted upwards by a small gauze swab held in a long slightly curved artery forceps This discloses a space between the nerve plexus and the subclavian artery in which lies a well-defined slip of muscle and tendinous tissue passing from the scalene muscles in the neck to Sibson s fascia (the supra pleural membrane) a pair of curved forceps is passed beneath this bundle which is then divided At once the subclavian artery in its thoracic portion is clearly exposed between it and the subclavian vein further forward a similar musculo tendinous band is seen and after being carefully isolated and cleared this too is divided The dome of the pleura with its overlying cap of fascial and extrapleural areolar tissue is depressed downwards by blunt pledglet dissection and the subclavian artery is thoroughly cleared of its fascial investment the internal mammary artery is seen passing downwards

and forwards from its parent vessel and the line of dissection proceeds along the course of this vessel in the extrapleural plane

The intercostal muscle bundle, vessels and periosteum of the first three ribs are then isolated posteriorly and divided with appropriate ligatures on the sectioned vessels The pleural dome is then peeled downwards, still in the extrafascial plane so that the front of the vertebral column is clearly exposed the dissection in this area may be complicated by the presence of enlarged lymphatic vessels and of dense posterior fixation of the lung and pleura, the dissection here may involve the use of the scalpel which is kept close to the ligaments in front of the vertebrae The oesophagus is seen and lateral to it lies a strong band of fibro-muscular tissue passing to the longus colli muscle and this is divided to relax the apex of the pleura in this particular recess. On the right side the pleura should be mobilized to the level of the azygos vein and on the left to the arch of the aorta so that the mobilized apex of the lung lies well below the level of the still unsectioned fourth rib In the large space so created a full view of the mediastinal structures is obtained * The incision is closed in two muscular and one skin layers with interrupted sutures of fine silk or 90 linen thread To prevent the apex of the mobilized lung from returning to its former site before the ribs regenerate the space may be filled with air for some weeks. The wound is not drained

Operative complications. Accidental opening of the pleura may occur during the resection of the ribs or the apicolysis The tears are difficult to suture until the surrounding area has been well mobilized If the tissues are not free enough to enable sutures to be passed without tension, the opening should be closed temporarily by a moist pack, the use of adjacent muscle tissue such as an intercostal bundle is of value. The intrapleural air must be aspirated at the close of the operation The thoroughness of this should be checked by observing the appearances noted on an immediate post-operative radiograph

Quite exceptionally during the course of an extrafascial apicolysis a chronic cavity with densely adherent walls may be opened, if the mobilization is thoroughly completed the cavity may then be sutured with unabsorbable stitches with satisfactory results (Price Thomas) The alternative is to proceed at once with a resection operation after the pleural cavity has been opened widely

Injury to the thoracic duct during the apicolysis may be detected during the operation, the injured duct should then be secured and ligated deliberately If the wounding of the duct is not seen at this time, the wound may fill up with chyle during the post-operative period

Minor leaks may become self-sealed, but if there is a lateral tear of the duct the outpouring of chyle may become serious at the second stage of the thoracoplasty which will be done earlier than planned originally, the duct will be sought and tied The tear usually takes place on the left side near the subclavian vein It is a rare complication

The two commonest structures to be damaged either temporarily or permanently are the sympathetic nerve chain and the phrenic nerve Trauma to the former is shown by a Horner's syndrome on the affected side associated with increased warmth of the hand, while the phrenic nerve injury is detected by noting a raised immobile diaphragm in the first post-operative radiograph Tingling down the distribution of the ulnar nerve for a few days is not uncommon if the retraction of the lowest part of the brachial plexus during the apicolysis has been heavy or prolonged

* A very full description, with excellent illustrations, of extrafascial apicolysis has been given by Price Thomas (1950)

The subsequent stages In the absence of complications the second stage of the operation is performed 10–14 days later In the standard upper partial thoracoplasty large segments of the fourth and fifth ribs (14–16 cm of the fourth and 15–17 cm of the fifth) are resected much smaller lengths of the sixth and seventh ribs are resected 10–12 cm and 6–8 cm respectively to allow the scapula to bed in well Extensive resection of the fourth and fifth ribs may produce paradoxical chest wall movements and it is often wise to resect these two ribs alone at the second stage and in certain patients with truly apical cavities the resection may stop at that

The scapula with such a limited resection fails to help in maintaining the collapse and various devices have been used to overcome this The lower half of the scapula may be resected or the angle of the scapula embedded anterior to the sixth and seventh ribs after an extrapleural strip has been performed to fashion a bed for it This latter manœuvre inevitably interferes with the movements of the arm and neither has gained wide support

Post-operative care The post-operative course depends largely on the type of lesion and the general condition of the patient bilateral disease depressed pulmonary function and a badly expanding lower chest wall may cause considerable post-operative difficulties In this respect an easy convalescence can usually be predicted for the good chronic ' in which operation is being performed for an upper lobe cavity without serious disease elsewhere whereas the opposite holds when thoracoplasty is being performed on a bad risk slipping chronic with slight pyrexia a high blood sedimentation rate and extensive disease with poor pulmonary functional reserve These patients tend to develop atelectasis of the lower lobe which may require bronchoscopic aspiration

Immediate post-operative treatment In spite of theoretical disadvantages morphine or omnopon relieves the considerable pain which inhibits coughing and breathing more than the depressant effect of the drug on the respiratory centre The relief of pain and the encouragement of efficient expectoration of bronchial secretions are essential measures in the prevention of collapse of the lower lobe The wound area should be firmly strapped but encasing strapping or bandages that impede the movement of the lower chest are not allowed Paradoxical movements of the chest in which the operated side moves in an opposite direction to that of the sound hemithorax during inspiration and expiration may cause cyanosis as air passes from one lung to the other with a rising tide of carbon dioxide for this reason the patient on return to the ward may need oxygen preferably given in a tent If the paradoxical movement is severe the front part of the chest should be steadied by a sandbag Routine physiotherapeutic supervision encourages diaphragmatic breathing corrects posture and encourages early movements of the shoulder The patient s own active efforts are the best preventative of scoliosis

Vomiting may be a troublesome complication and is best avoided by a reasonable limitation of the fluid intake by mouth for the first 36 hours the fluid requirements are made up by the use of rectal salines or exceptionally by the intravenous route especially if vomiting has upset the fluid and electrolyte balances Vomiting is only seen in patients with paradoxical movements and is probably due to the effects of a raised carbon dioxide content in the blood

Major complications of thoracoplasty

Atelectasis Collapse of the lower lobe though often transient and without serious sequelae is a major complication its early detection and treatment have been described on page 86 If it persists secondary infection in the lobe may cause severe toxaemia associated with pyrexia malaise and loss of appetite even if serious secondary infection

does not follow, the lobe may fail to re-expand and this will require a far more extensive thoracoplasty to be carried out than was originally intended or require later a lung resection if bronchiectatic changes develop

Bleeding into Semb's space A rapid increase of the fluid in the space associated with obvious clinical and haematological signs of anaemia will indicate this complication, it is treated conservatively by accentuation of rest and quiet and by blood transfusion, the wound will rarely require re-exploration Occasionally the wound will bulge and to prevent the risks of its disruption the fluid should be aspirated and streptomycin or penicillin instilled into the space A specimen of the aspirated fluid is submitted for bacteriological examination, for the sudden increase in fluid in the space may be an indication of pyogenic or tuberculous infection, for which appropriate treatment is necessary If pyogenic infection does not respond to the appropriate antibiotic agent given parenterally and locally, the space is drained by a tube well away from the line of the main incision after such drainage the second stage of the operation should be performed as soon as possible if the patient's condition warrants it, as the bedding-in of the scapula after further rib resections will obliterate or limit the area of dead space

A chronic tuberculous infection of Semb's space is serious and before the days of streptomycin was usually a fatal complication, but the results of daily instillation of streptomycin have given us a weapon of great efficiency

The late development of sinuses is not uncommon and, though often associated with the discharge of suture material from a wound that has perhaps been re-opened for two further thoracoplastic resections, should also arouse the suspicion of a tuberculous infection and bacteriological examinations are always called for

Modifications of thoracoplasty

Many operations have been designed to replace the standard thoracoplasty just described, chiefly with the object of achieving better cosmetic results The extensive resection of large parts of the upper seven ribs inevitably causes deformity, however unnoticeable this may be when the patient is clothed, but scoliosis and a bad neck position will occur if the co-operation of the patient is not achieved by the physiotherapist, and the transverse processes have been removed It is well to remember that the extensive use of extrapleural artificial pneumothorax, just before the last war, was partly encouraged by the hope that extensive thoracoplasty would be avoided, but the results were unsatisfactory and the operation has largely lost its place in this country

The disastrous results that followed the old plombage operation in which paraffin wax was moulded into an artificially created space included ulceration of the paraffin pack into the cavity (with subsequent expectoration of the wax) and infection caused by the discharge of the material through the wound, these complications have not been repeated on such a scale after the use of the newer compressive agents such as polythene or lucite, but even these have the continued disadvantage that they are foreign material bodies It is hard to believe that they are as efficient in their effects as the permanent collapse and downwards displacement of the apex of the lung produced by Semb's operation, in which regenerated and shortened ribs take up a permanent position at an ideal level and produce a lasting selective relaxation In some reports these materials have been responsible for infection and necrosis of the overlying ribs

In discussing these modifications it is difficult to write without prejudice, but the good results of the modern upper thoracoplasty combined with apicolysis with regard to sputum conversion and elimination are such that arguments in favour of cosmetic appearances

might not be accepted as valid unless the ultimate object the closure of the cavity is as good after the less destructive operation as after formal thoracoplasty O Brien (1950) writes trenchantly on the subject we go on our way embellishing techniques or substituting some new bizarre and often ridiculous measures which accomplish less than the ones they are intended to supplant

Some alternatives to thoracoplasty

The varieties are almost innumerable in essence they consist of attempts to mobilize the apex of the pleura both vertically and laterally without the sacrifice of many rib segments the re-expansion of the upper lobe is prevented by suturing portions of stripped periosteum to newer sites or by filling the apicolysis space with unabsorbable materials of which the modern ones most frequently used are lucite or polythene Of these two procedures the one avoiding artificial packs or plombage has more to commend it theoretically for the surgical aversion to large masses of foreign body material is deep-seated and well founded In the chest such material however inert may produce pressure necrosis and some accounts speak of the ulceration of lucite into the neck and mediastinum and the wound itself while the polythene pack may cause a slow effusion which may rupture into a bronchus or through the wound But exceeding all these disadvantages which in some papers have been rare happenings is the poorer results in sputum conversion and at the time of writing this resuscitation of the method of plombage has not been widely accepted though surgeons have written of good early results (Morriston Davies 1951 Cleland 1950)

In considering these procedures together with a combination of artificial pneumothorax O Brien says when the extrapleural space is maintained by air these complications are almost the same as just described (i e those after artificial pneumothorax) but many surgeons are not satisfied with this debacle and fill the space with all sorts of foreign bodies The use of these procedures is haphazard unscientific inexact and inexcusable We have seen small cavities change in position but not in size under a 90 per cent collapse with pneumothorax or thoracoplasty How therefore can anybody without Divine Guidance know how much paraffin or how many lucite balls will be necessary to cause cavity closure? Furthermore once they are put to the space they obscure the X ray examination and one cannot tell whether the cavities are closed or not

Attempts have been made to decrease the deformity of the classical thoracoplasty by limiting the extent of resection and by preserving the first rib intact The technical difficulties of performing Semb s extrafascial apicolysis with an intact first rib are obvious though mobilization in the extrapleural plane is easily obtained If the apex is displaced downwards by extrapleural dissection re-expansion of the upper lobe takes place unless active compressive agents such as air paraffin or plastic materials are used this tendency to re-expansion can be better prevented by the operation of periosteoplastic pneumonolysis as described by Edwards (1940) It is only fair to state that Edwards has abandoned this type of modified thoracoplasty A description of it is given because this operation may occasionally be the best method available for the treatment of a few isolated examples with small cavities not of obvious tension type

The advantages of this operation would seem to be as follows

(1) The advantages of the pneumolysis without need to employ a foreign body material the space being obliterated by living fibrous tissue and lung tissue which is achieved by a particular type of mobilization of the periosteum of the ribs and re attaching them in newer sites

(2) A permanent collapse obtained without gross bony deformity of the thoracic cage by an operation that can be completed in one stage

The operation described has advantages over the extraperiosteal pneumolysis described by Bailey (1942), because it mobilizes the lung more fully especially anteriorly and prevents re-expansion by suture of the divided bands of the posterior ends of the periosteal tubes at a lower level

The operation of pneumoplasty (F R Edwards, 1949)

After the upper ribs have been exposed by a peri-scapular incision a large section of the fourth rib is resected sub-periosteally, the periosteum of this rib space is then incised and an extrapleural mobilization of the pleura and underlying lung is carried out as in the operation of extrapleural pneumothorax (see p 223) When the space has been fully developed about 20 cm of the fifth rib is resected, extra care being taken to preserve the periosteum of the inner surface of the rib The outer periosteum of the sixth rib is incised along the lower edge and elevated to its upper border over a wide extent (20 cm) The inner periosteum is then closed and freed as a mass together with the fifth intercostal bundle The second rib may be dealt with in the same way, no ribs are resected except the above-mentioned segments of the fourth and fifth

The outer and inner parts of the periosteal cuffs of the second and third ribs are raised with division posteriorly of their intercostal bundles · the back ends of the freed intercostal bundles, vessels, nerves and periosteal tubes are sectioned and a large flap hinged anteriorly is then fashioned The intercostal bundles and periosteum are sutured down to the ligamentous structures at the side of the vertebral column

The periosteal cuffs are then spread out and sutured together in pairs so that when these regenerate a large bony block will form in a rear position best suited to prevent re-expansion of the upper lobe to the extrapleural space that has been artificially created. To maintain the extrapleural space until the ribs have regenerated, air is injected into it, starting at the end of the second week when the post-operative fluid in the space is absorbing re-fills are continued until the sixth or eighth week

A complication that has been noted in some clinics after this operation has been a late necrosis of ribs

Modern methods of plombage

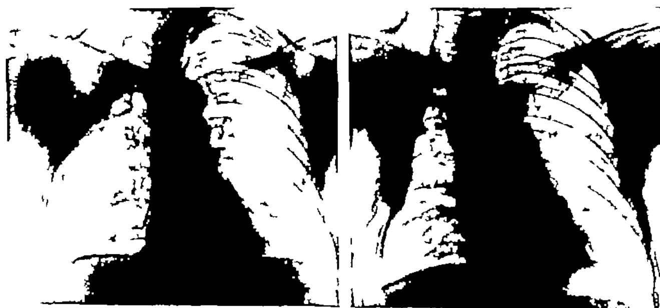
The orthodox objections to plombage that have been expressed may be lacking in fairness and a personal failure to achieve enthusiasm may be based on obstinate prejudice An uncompromising condemnation of paraffin plomage is based on observations made on patients treated by this method in different clinics throughout the world with disastrous results, of which severe chronic wound infection and bronchial fistula were the most important It has no place in modern surgery Recent work by Morriston Davies, and Lucas and Cleland, presents a more favourable picture These surgeons presented good results after thoracoplasty from the point of view of sputum conversion but have expressed their dislike of the resultant deformity, of the need for multiple staged operations and because of the high incidence of post-operative complications such as atelectasis of the lower lobe Cleland has had as good results from thoracoplasty with plombage, using polymethyl methacrylate or polyethylene, the former in the shape of hollow spheres, the latter as solid balls, as after the modern type of thoracoplasty with apicolysis as far as sputum rates are concerned, the advantages of his operation, in his hands, have been the retention of an intact thoracic wall, the necessity often for only one stage and a notable decrease in the post-operative complications, especially those of paradoxical chest wall movements and

atelectasis His paper based on 125 cases with 3 deaths (none attributable to the plombage itself) and with only 5 post-operative examples of atelectasis should be read carefully there were 3 space infections (2 being staphylococcal and 1 tuberculous) and 5 instances of wound rupture the latter complication he believes is due to the collection of fluid under tension in the space and this is now prevented by aspirations

An important feature of his operation is a really thorough extrafascial dissection the plombage being used to prevent loss of the advantages of such a thorough vertical and lateral relaxation of the upper lobe and its overlying parietal pleura the extent of the rib resection is half of the third rib and most of the second, the periosteum of the first and lower ribs is stripped from the deep surfaces of those bones and the intercostal bundles are divided posteriorly and carried forward with the mobilized lung the denuded ribs being left intact The early results of this operation are satisfactory

Revision thoracoplasty

An upper thoracoplasty may fail to close a cavity because of inadequacy of the rib resection failure to get a good extrafascial apicolysis or because the patient was primarily unsuitable for the operation and should possibly have had a lobectomy instead of rib resections the latter group consists largely of those patients with severe atelectasis of the lobe associated with a cavity and endobronchial disease Even if the cavity is closed



(a) (b)

Fig 9-27

(a) An inadequate upper thoracoplasty has failed to close the cavity
(b) After revision thoracoplasty

Cavity closed sputum persistently negative on culture for year bacilli then re-appeared and a right upper lobectomy has since rendered it negative

radiologically the sputum may remain positive because of a tuberculous bronchiectasis in the collapsed lobe

If the thoracoplasty and the apicolysis have been adequate and the sputum remains positive with radiological evidence of cavity persistence or bronchiectasis it is unwise to re-operate in the hope that further resection of regenerated ribs with re mobilization of the apex will be successful Other measures such as resection or rarely open cavity

drainage are often preferable But revision thoracoplasty is worth doing if thoracoplasty is indicated and when it is known that a full apicolysis was not achieved

If revision operations are carried out the points of importance are to ensure that all the front stumps of the second, third and fourth ribs are resected in addition to the regenerated plaques of bone and that a full apicolysis is done This latter procedure is extremely difficult if a partial extrafascial apicolysis has been done, it is then commonly seen that Sebileau's bands have not been fully divided, the one most commonly overlooked being that which holds up the apex of the pleura to the region of the longus colli muscle in the posteromedial recess of Semb's space In addition to the possible risk of injuring subclavian vessels because of the distortion of the anatomy, it is possible to open the cavity posteriorly where the lung and pleura may be densely adherent to the ligamentous structures in front of the vertebral column

The management of a cavity accidentally opened during extrafascial apicolysis

Whether a cavity be opened during a primary apicolysis or during a "corrective" thoracoplasty, the lines of management laid down by Price Thomas offer the best chance of success apart from carrying out an immediate lobectomy or segmental resection This surgeon points out that apart from faulty technique, such as ill-applied swab or finger dissection, the cavity may be opened when the ulcerative processes have so spread that part of the cavity wall is formed by the periosteum of the vertebral bodies

If the disaster happens the cavity should be carefully mopped out and filled with gauze, the mobilization of the apex should then be completed, as any attempt to suture the torn cavity will fail unless all tension has been relieved, the mobilization in fact should be more extensive than that originally planned Thorough bedding-in of the scapula is achieved by increasing the extent of rib resection, possibly including the eighth rib If mobilization has been really thorough the cavity can be sutured after excision of the torn edges and the suture line buried by further layers of invaginating stitches If this cannot be done adequately, a lobectomy is indicated

EXTRAPLEURAL PNEUMOTHORAX

This procedure (Tuffier, 1891) has declined in popularity in Great Britain since the immediate pre-war era when a considerable wave of enthusiasm supported its adoption Apart from the risk of infection in the artificially created space the method has the defects of attempting to replace the need for a permanent collapse by a temporary measure, previously justified on the assumption that conditions in the same lung or that of the other side made artificial pneumothorax impossible or thoracoplasty too dangerous Experience has shown that good results are only rare after an extrapleural pneumothorax has been abandoned because of the frequent re-appearance of a cavity temporarily closed by high-pressure air fillings, or that the collapse attained has proved to be permanent and irreversible This latter experience has led some surgeons (Reid, 1946) to employ the operation as a temporary measure, preparatory in itself for a later permanent thoracoplasty As Rafferty (1944) says, "it possesses all the disadvantages of a permanent measure with none of the advantages"

The few remaining indications for this attractive but disappointing operation would seem to be

(1) In an occasional patient with bilateral disease unfit for thoracoplasty and yet

presenting insistent demands for cavity closure unobtainable by other means this group might include patients who have undergone a successful thoracoplasty on one side and have developed a cavity in the upper lobe of the other lung which cannot be controlled safely by other measures or those with bilateral disease with a pneumothorax on one side that controls the disease but in whom tuberculous cavitation is proceeding in the other lung when pneumothorax or thoracoplasty is inadvisable for different reasons

(2) As a preparatory measure when thoracoplasty will be used later to produce a permanent collapse

(3) In children in whom thoracoplasty would produce a grave scoliosis and where a pneumothorax is contra indicated or unobtainable The aim in this group will be to complete the operation by thoracoplasty as soon as growth has ended and the danger of adolescent post thoracoplasty scoliosis has passed

Complications of extrapleural pneumothorax

These are mainly (1) post-operative bleeding into the space this may be alarming on rare occasions endangering life but it is chiefly dangerous because of the added risk of (2) infection in the space Infection in the space may be either pyogenic or tuberculous and on theoretical grounds this can be checked or prevented by suitable antibiotics or chemo therapy The rate of infection is given variously as 15 or 37 per cent (3) Failure of the lung to re-expand after a reasonable period of re-filling in the absence of infection and in the face of a closed cavity this complication need not be serious as the space could be obliterated safely with a small thoracoplasty or by the use of oleo-thorax (4) The rupture of the cavity into the extrapleural space this happens if a totally unsuitable case has been selected in which the cavity wall obtains a large part of its blood supply from the chest wall

The technique of the operation

In choosing a patient for this operation it is unwise to regard it as a slight procedure or in the nature of a minor operation for the attempt to produce an extrapleural pneumo thorax space of small dimensions will always be a failure Complete separation of the apex of the pleura on all sides including a strip on the mediastinal surface to the aorta on the left side and below the azygos vein on the right is required The post-operative re fills of air must be able to compress the lung from above downwards as well as concentrically and this extensive operation must certainly be classed as a major procedure carried out with all respects to the modern demands for anaesthesia anti shock and anti infective therapy The anaesthesia of choice is local novocaine infiltration of the brachial plexus the upper seven intercostal nerves and the muscular planes exactly as for upper thoracoplasty

A large segment of the fourth or fifth rib is resected with meticulous separation of the periosteum from the bone The periosteum is carefully incised along the whole length of the exposed rib bed and the divided edges are held up in curved artery forceps The muscular fibres deep to the periosteum are separated carefully to expose the areolar tissue of the endothoracic fascia once this layer is exposed its cobweb nature is obvious and its blunt dissection with small pledglets on long artery forceps produces a characteristic creaking sound This space is developed above and below the line of incision in the periosteum and when an adequate space has been created a small rib spreader is introduced the extra pleural space can then be developed rapidly by blunt dissection As soon as the apex of the parietal pleura is reached a good illuminated probe or spatula is brought into use The first rallying point is the intrathoracic portion of the subclavian artery and there is usually a considerable amount of areolar tissue around this vessel as it lies in the mediastinum

and the apex of the pleura will strip down readily, more medially the phrenic nerve will be seen lying on the superior vena cava on the right and the subclavian vein on the left Care must be taken in its vicinity as there are small veins here, exact haemostasis is essential at all stages, if one area is tending to ooze a dry gauze mop should be left there for several minutes while the work of blunt dissection proceeds in a drier easier area small vessels on the chest wall are sealed off by touching with a diathermy point a long pair of forceps affixed to them Occasionally rather stout bands of fibro-areolar tissue passing to the pleura from the parietes require scissor division

When the pleura has been displaced down to the level of the eighth rib posteriorly and to below the azygos vein or to the level of the aorta on the mediastinal surface and to the lower border of the fourth rib anteriorly, the space should be packed for a few minutes with dry gauze swabs, when these are slowly removed any bleeding can be checked either by diathermy or by the use of fibrin-plasma solution When the space is dry the incision in the posterior wall of the periosteum is closed by a continuous suture (nylon or catgut), and the space made airtight; though theoretically difficult this is not so in practice, and a satisfactory seal is achieved The wound is then closed in layers

At the close of the operation the first re-fill is given through a needle placed usually in the third intercostal space anteriorly and enough air introduced to produce a pressure of + 15 cm of water

Post-operative management

Cough should be checked by morphia and the patient propped up as soon as reasonable, the routine observations on the colour, pulse rate and blood pressure will determine the presence or absence of bleeding and blood transfusion will be given as indicated

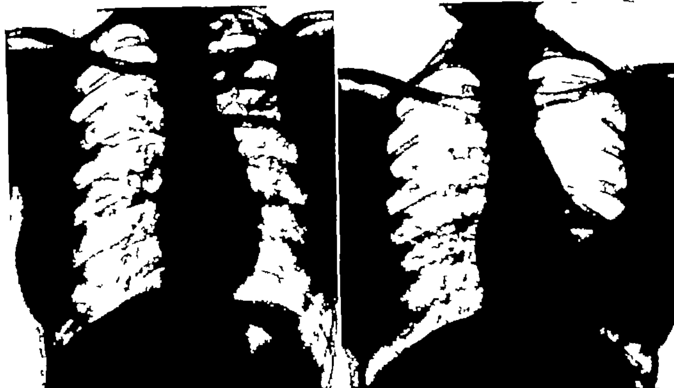
On the day after operation portable radiographs are taken A fluid level is seen usually, due to the oozing of blood and serum into the space, this sero-sanguinous fluid should be removed by the needle and a further re-fill of air given to produce a pressure of between + 15 to + 20 cm of water

As soon as possible the positive pressure rate of the re-fill should be diminished and it is a mistake to maintain high pressure re-fills too long, once the separated pleura with the underlying lung has become covered with thick fibrinous tissue the re-fill should approximate to the type associated with an intrapleural pneumothorax If the original selection of the patient for the operation has been based on the need to provide temporary relaxation the extrapleural pneumothorax should be slowly abandoned after two years, but in most patients the safest course to adopt is to achieve permanent collapse by a small thoracoplasty

In Great Britain this procedure is only rarely employed and few surgeons adopt it to any extent J. E H Roberts, an early enthusiast for the operation in 1937 and in 1938, had largely discarded it in his post-war practice because of the poor results. His opinion was based, together with others, on the failure of an operation that had a higher mortality rate than thoracoplasty (8 to 10 per cent) and is dogged by complications such as a rupture of the cavity and empyema formation into the space Perhaps the general impression that the operation is an unsatisfactory one is due to its application to hopeless risk patients and to the high preponderance of bilateral disease in the series reported My own feeling after an initial enthusiasm for the operation is that it will not gain a permanent place in thoracic surgery

Its application has been sponsored in a more favourable light by Cutler (1951) who advocates a resuscitation of the method In a series of 129 operations on 121 patients

(8 being bilateral interventions) there were 17 operative deaths (13 2 per cent) most of the deaths however, were in the early part of the series before improved techniques and streptomycin were available Cutler now believes that the operative mortality can be regarded as less than 4 per cent in spite of the fact that the operation is used in that group of patients who have serious disease not amenable to other collapse procedures because of the severity of the lesions Included in the patients selected were patients with bilateral disease with



(a) (b)

Fig 9 8

(a) Bilateral disease in a woman aged 24

A large cavity in the left upper lobe with scattered area of disease in the same lung complicated by a lesion i the right upper lobe Perhaps the better line of treatment would have been hazardous left thoracoplasty with a right artificial pneumothorax, but a left extrapleural pneumothorax was adopted with satisfactory result.

(b) Six months after a left extrapleural pneumothorax had closed the large left upper lobe cavity

The right artificial pneumothorax has been abandoned. Sputum negative

active tuberculosis not responding to conventional methods and elderly subjects in the fifth and sixth decades Finally the operation has been used in young women especially those who resist the idea of thoracoplasty

Unlike most supporters of the operation Cutler does not advise stripping the medial aspect of the lung from the mediastinum but advocates a most extensive extrapleural freeing elsewhere He has found streptokinase and streptodornase of value in the management of post-operative coagulation within the space

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CHAPTER 10

RESECTION OPERATIONS AND THE DRAINAGE OF CAVITIES

RESECTION

Since incision and excision are used widely in surgery it is not surprising that direct attacks upon the persistent reservoir of tubercle bacilli in the lung have been made the first successful resection being performed in 1895 by Macewen of Glasgow (1906) Since then tuberculous cavities have been treated by open drainage (speliotomy) by closed drainage (Monaldi) by direct exposure either through an adherent or free pleura with deliberate opening of the cavity followed by suture of the walls together (Cleland and Dilwyn Thomas) and by actual resection of the diseased lung lobe or segment combined sometimes with removal of the associated parietal pleura (pleuro-pneumonectomy extra pleural lobectomy) At the moment of writing actual excision of tuberculous areas has almost completely replaced the drainage of tuberculous cavities

Surgical resection of pulmonary tissue might appear hazardous from theoretical reasons The rupture of a cavity into an artificial pneumothorax the development of a lung fistula or the accidental opening of a cavity during thoracoplasty has often led to a disastrous tuberculous infection of the pleura or of the extrafascial or extrapleural space and these catastrophes made physicians and surgeons in the past loth to risk the dangers of direct operation on the tuberculous lung itself Deliberate resection of lung tissue is however quite different from the accidental opening of tuberculous tissue and can be executed without the spread of disease to the pleura or the extracostal tissues though a tuberculous empyema may follow The decision to employ resection remains a difficult one though the indications are becoming clearer each year

Some historical points

The first important report on a series of resections for tuberculosis made by Thornton and Adams (1942) showed a mortality rate of 45 per cent after pneumonectomy and 25 per cent after lobectomy but these were gravely ill patients unsuitable for thoracoplasty and denied the present-day advantages of individual hilum dissection technique and of streptomycin In 1943 Churchill and Klopstock presented an encouraging report on a small series of patients carefully selected not as candidates for last hope salvage operation but on physiological and psychological grounds and there were no deaths This series represented the first serious challenge to thoracoplasty as the ideal operation for patients with fibro cavernous and caseous disease Immediately after this many sub total resections were done with too little attention paid to effects on disease in the other lung or the remaining lobe of the same side The acceptance of bad risk patients kept the mortality rate high

Overholt (1945) was able to report on a large series of 196 resections with 46 deaths (24 per cent) By the end of 1948 Sellors and Hickey had only 5 deaths after resection had been adopted deliberately in 55 patients with tuberculous lesions and in only one third of these had streptomycin been used

The application of Waksman's discovery of streptomycin and the replacement of the old tourniquet method of resection by meticulous hilar or lobar dissection led to a great decrease in mortality and post-operative morbidity figures and at the American meeting of

Thoracic Surgeons in 1948, 475 resections, carried out with the help of streptomycin, were collected and gave a mortality rate of 9 per cent The effect of the antibiotic is indicated by the figures of Bailey, Glover and O'Neill (1949)

200 RESECTIONS

	100 without streptomycin	*100 with streptomycin*
Complications .	49	10
Deaths	17	2

With careful selection and better technique these figures are being followed by reports from other clinics throughout the world, the biggest series published in Great Britain by Edwards (1951) and his colleagues giving a mortality rate of 2·5 per cent in over 200 resections.

The ultimate result remains to be assessed on a five-year follow-up but resection is established and safe in the treatment of many chronic forms of lung tuberculosis Better results are being achieved by improved selection and technique, by conserving as much healthy tissue as possible and by adopting appropriate measures to decrease the size of the hemithorax whenever doubt exists as to the condition and physiological state of the remaining lung tissue

Indications for resection

Resection is not usually advised when less drastic procedures such as bed rest and streptomycin are likely to succeed , but already it has displaced thoracoplasty and pneumothorax in many situations Ideally the contra-lateral lung or the area to be spared on the side of operative excision should be healthy or stable and possessed of adequate function Normally the disease should be chronic in type, but resection may find a place in the treatment of unilateral acute exudative disease and as an emergency measure for ruptured tuberculous cavities (Fig 10 13) and for severe haemoptysis uncontrolled by less radical procedures (Fig 10 14)

The immediate results of resections are so pleasing to surgeon and *patient that the gate into a field of almost limitless extent is invitingly open* Edwards (1951), convinced of the malignity of tuberculous lung lesions, advocates and *practises* resection on a wide scale, often for quite small, comparatively early lesions , the immediate results are brilliant. He and his associates have performed 250 resections, many for early disease Of 200 patients who had passed the immediate post-operative stage (3 months) 93 per cent had negative sputum at the time of the report, which dealt with a considerable number of less than one-year follow-up cases the mortality rate was only 2·5 per cent Of 30 patients followed for over a year and 100 for six months, 6 7 per cent had positive sputum 10 empyemata and 6 fistulae were the major complications in the first 100 patients operated upon About 55 per cent of *those patients who had undergone resection would previously have been* regarded as suitable for thoracoplasty

Further evidence of the mounting confidence in the resection of tuberculous lesions is provided by the remarkable work of Chamberlain and Klopstock (1950) who have performed segmental resections in over 250 patients with a mortality rate of 2·4 per cent their complication rates to date have been astonishingly low, with only 6 examples of post-operative broncho-pleural fistulae These patients have naturally been selected with great care, the operations being performed only when there existed good clinical, radiological and haematological evidence of fair resistance in associated *minor lesions that would not be removed at the time of resection.*

Sweet (1950) on the other hand provides evidence that early over-optimism may be dangerous following a recent review of at least a four years follow up after excisions used in the treatment of 63 tuberculous patients before streptomycin was available He reduced the indications for resection to patients with irreversible bronchiectasis, with lower lobe and occasionally middle lobe cavities and to those that persist after thoracoplasty and possibly for tuberculoma If the patient was suitable in the first place for thoracoplasty, that operation was preferred to resection

Of the 63 patients 27 had undergone lobectomy 36 pneumonectomy In three or more years after the lesser resection 9 were dead 6 were alive but with active disease and 12 were well out of the 27 The pneumonectomy results were 19 dead 3 alive with active disease and 14 well This careful post-operative analysis is not only a corrective to over enthusiastic adoption of resection measures bolstered up by the usual good immediate results but will serve as a yardstick by which the results in patients having the advantage of streptomycin therapy in the pre and post-operative periods can be measured Considering 19 deaths that occurred well after the immediate post-operative phase (7 after lobectomy 12 after pneumonectomy) Sweet says It is more than ever apparent therefore that even though the major focus of disease can be excised surgically any of the smaller remaining areas may at some future time become the site of activity of the infection This seems to re-emphasize the importance of the immunological aspect of tuberculosis ' Sweet s results were based on a particular group of patients operated upon under certain conditions prevailing at the time (1944–45)

We must now await the results after 3–5 years of a large enough series of resections carried out on a more favourable group of patients and with better surgical techniques aided by streptomycin therapy At the time of writing however the brilliant results of Edwards and his colleagues and of Chamberlain and Klopstock indicate that the wave of popularity for excision is rising Its use in such a condition as pyo pneumothorax with a grossly diseased underlying lung (now treated by pleuro pneumonectomy) is increasing largely as the result of Sarot s work (1949)

Great reliance is still placed on upper thoracoplasty with apicolysis for the chronic upper lobe cavity At Yardley Green Hospital Birmingham in the four years up to July 1950 306 patients were subjected to thoracoplasty with 6 deaths (approximately 2 per cent mortality rate—MacHale and d Abreu) In three years ending December 1950 180 resections have been done with a mortality rate of about 6 per cent (d Abreu MacHale Brain) with sputum conversion in both series about 80–85 per cent The comparison is not altogether fair because the resection group included some poor risks At the time of writing the resection rate in the area is steadily increasing

Dangers and advantages of resection operations

In the days of the tourniquet amputation method for excision of bronchiectasis mishaps were noted occasionally when the underlying pathological cause was tuberculous disease either of the bronchus itself or of the neighbouring lymphatic glands In 23 accidental resections for tuberculous disease Sellors and Hickey (1949) noted that six patients died as the consequence of the operation Appreciation of the subsequent complications of tuberculous empyema of spreads to the remaining lobe or to the other lung or the persistence of a broncho-pleurocutaneous fistula had two important effects firstly it showed that a thorough search for tubercle bacilli in the sputum from patients with bronchiectasis should be made before lobectomy is undertaken and bronchoscopy employed more frequently for the detection of tuberculous endobronchitis secondly it promoted a great distrust for the

operation of excision in tuberculous disease The development of tuberculous complications after the old tourniquet, sub-total lobectomy was to be expected, but with the great improvement in the surgical technique of hilar dissection in lobectomy these disasters are largely avoided Streptomycin, whatever the ultimate result of its application may prove to be, encouraged a newer confidence and there is now no hesitation in employing resection in patients with known tuberculous bronchiectasis

Lesions more suitable for resection than collapse measures

In selecting patients for primary thoracoplasty it has already been seen that this operation is often preferred to the less drastic procedure of artificial pneumothorax because of its permanent efficacy and the decreased likelihood of atelectasis or fluid formation in the pleural cavity developing Questions are now being asked, when the possibility of thoracoplasty is under consideration, about its chances of closing the cavity The possible efficacy of collapse procedures is always in doubt when the lesion under review is incapable of being relaxed or compressed

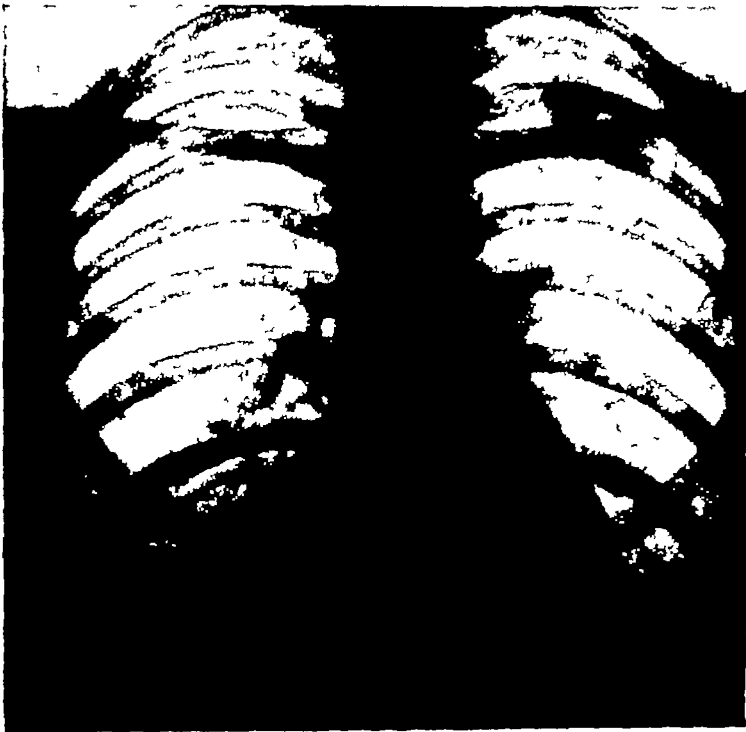


Fig 10 1



Fig 10 2

Fig 10 1 —Cavitation in left upper lobe "tuberculoma"

The patient, a young woman of 25, was radiographed two years before this as a contact case a solid shadow was then detected she remained in good health Control radiographs were taken at three monthly intervals, and the cavity noted in the solid mass seen above was regarded as an indication for resection Tubercle bacilli were recovered from this cavity after resection

Fig 10 2 —Lobectomy specimen

By present-day standards the excision was unnecessarily wide

(*a*) *The "tuberculoma" or massive nodular disease* is obviously incapable of being altered by pneumothorax or thoracoplasty This type of conglomerate tuberculous focus usually runs a benign course and may often be detected by routine radiology, it can, however, break down suddenly and rapidly spread tuberculous infection throughout the bronchial tree Presenting as a mass on the radiograph it may be mistaken for a tumour, innocent or malignant it is usually treated best by thoracotomy and resection, as it has an unpleasant habit of breaking down into a cavity Its removal should, if possible, be local, either by

segmental resection or by resection-enucleation It presents as a massive encapsulated focus in which either caseation or cellular reaction may predominate and is sometimes a completely blocked cavity

Tuberculomata may be multiple or one may be present elsewhere in a lung containing



(a) (b)

Fig 10-3

(a) Consolidation of right upper lobe in male aged 40 years.

Haemoptysis [illegible] sputum positive General condition good with no pyrexia, but there had been thr[illegible] small haemoptyses Thoracotomy and right upper lobectomy were undertaken. The tomograph shows cavities in consolidated area. The shadow near the axilla is due t[illegible] old lipiodol.

(b) Radiograph taken one year after lobectomy: the patient has now been at full work for 18 months.

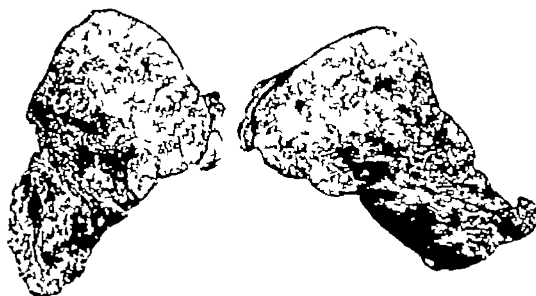


Fig 10-3 (c) —Solid pneumonic disease right upper lobe

Treated by lobectomy See Fig 10 3 (a) for radiological appearance.

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Lesions more suitable for resection than collapse measures

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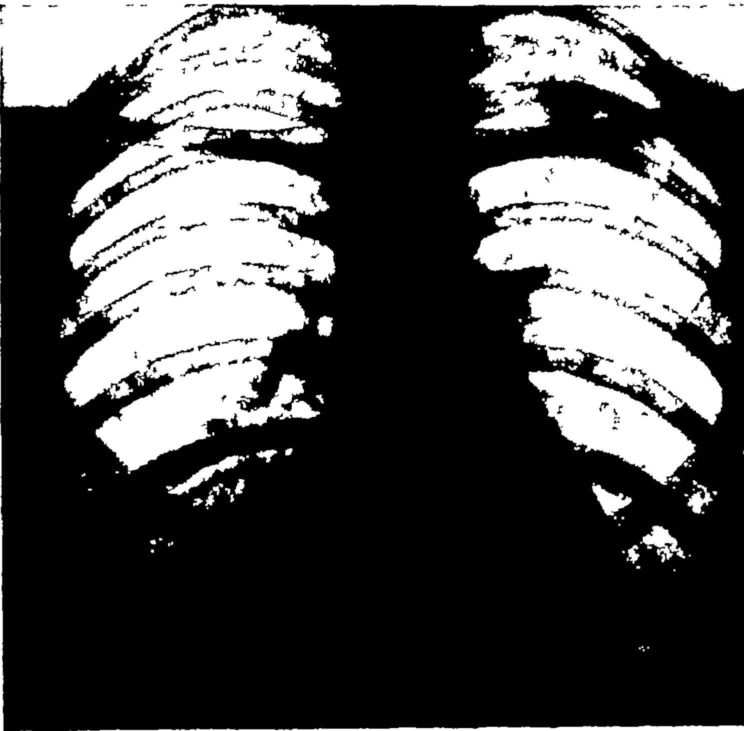




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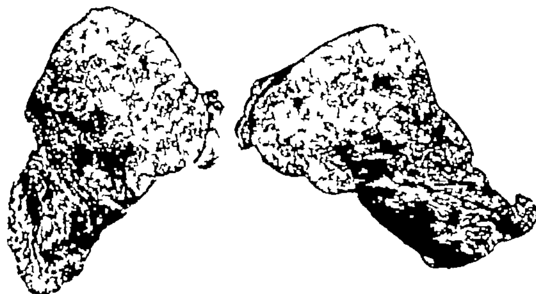


Fig 10-3 (c) —Solid pneumonic disease right upper lobe

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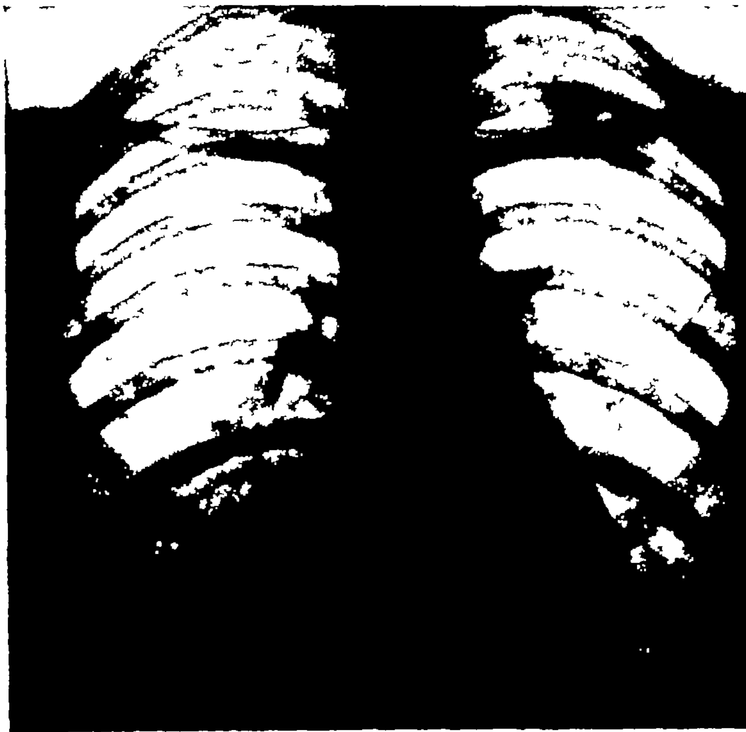




FIG 10.1 FIG 10.2

FIG 10.1.—Cavitation in left upper lobe "tuberculoma."

The patient, a young woman of 25, was radiographed two years before this as a contact case; a solid shadow was then detected. She remained in good health. Control radiographs were taken at three monthly intervals, and the cavity noted in the solid mass seen above was regarded as an indication for resection. Tubercle bacilli were recovered from this cavity after resection.

FIG 10.2.—Lobectomy specimen.

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a cavity the practicability of removing this type of lesion locally adds a valuable weapon to the resection programme

(b) *Tuberculous bronchitis and destroyed functionless lungs* These cannot be relaxed or compressed by phrenic nerve interruption artificial pneumothorax or thoracoplasty because the rigid dilated bronchi and their surrounding solid parenchyma are uninfluenced by such measures

Tuberculous bronchiectasis is seen in its truest form when a stenosing tuberculous endobronchitis has caused pulmonary collapse with associated dilatation of the bronchi The copious positive sputum the shrinking of the overlying chest wall, the distortion of the mediastinum to the side of the disease the bronchographic appearances and the demonstration of a tuberculous endobronchial lesion in the main stem bronchus provide a classical



FIG 10-5 —Histological appearance of tuberculosis in bronchus of a lung removed for tuberculous bronchiectasis. (Prof J W Orr)
Photograph by Dr J G Jackson, University of Birmingham.

picture No collapse measure can cure this condition and if the other lung is good the treatment is by pneumonectomy usually followed by a later thoracoplasty designed chiefly to prevent over-distension of the remaining lung especially if this shows evidence of healed or quiescent tuberculous disease

Not always will a tuberculous stenosis or the presence of tuberculous granulation tissue be seen in these patients The lung may have become atelectatic during previous collapse therapy and if re-expansion has not been obtained quickly bronchiectasis will almost inevitably develop

In some patients atelectasis and subsequent bronchiectasis may develop during an artificial pneumothorax and again pneumonectomy is often indicated and practised

Resection for tuberculous bronchiectasis not only rids the patient of the troublesome symptoms of constant cough and expectoration of a large area of sepsis that may terminate in severe toxaemia and even amyloid disease but aims at stopping the spread of tuberculous



(*a*)

FIG 10 4

(*a*) Bronchiectasis shown by lipiodol bronchography of a long-standing example of pulmonary tuberculosis (six years) with persistently positive sputum





(*b*) (*c*)

FIG 10 4

(*b*) After left pneumonectomy

(*c*) Conservative thoracoplasty with retention of first rib

There is fluid in the extracostal space (Radiograph taken three days after five rib thoracoplasty conserving the first rib)

a cavity the practicability of removing this type of lesion locally adds a valuable weapon to the resection programme

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FIG 10 5 —Histological appearance of tuberculosis in bronchus of a lung removed for tuberculous bronchiectasis. (Prof J W Orr)

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disease to the other lung The hazards of this operation on a chronically ill patient may appear great but in practice the results are good and provide one of the firmest indications for resection

The "destroyed" lung Extensive unilateral disease with extreme fibrosis or multiple cavities (Fig 10 6), or with one or more cavities in the upper lung and a completely atelectatic lower lobe, not only destroys most of the respiratory function on that side but is the source of copious sputum containing tubercle bacilli Thoracoplasty is ineffective and leaves the patient with the symptoms of bronchiectasis and such lungs should be resected if the other side is sufficiently sound

(c) *Bronchiectasis with tuberculous empyema* If the other lung is sound, pneumonectomy is often indicated for patients with an associated tuberculous empyema This complication

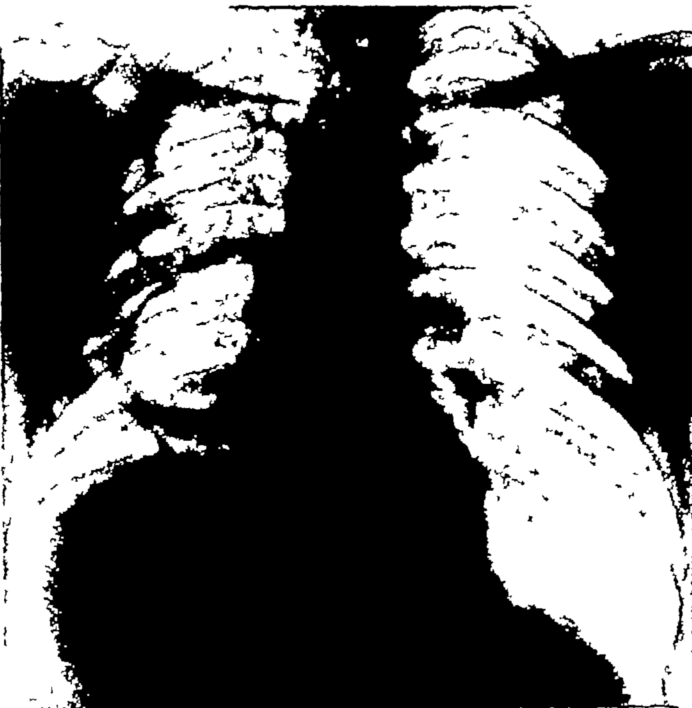


Fig 10 6

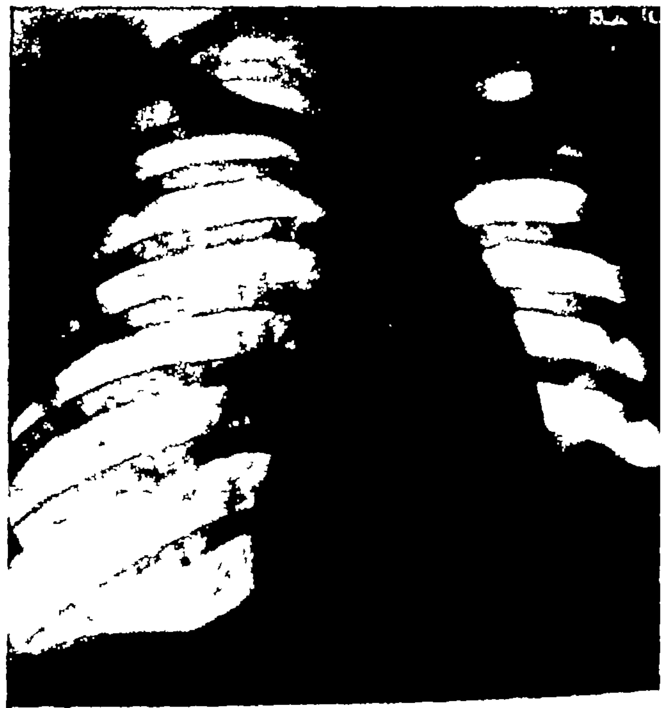


Fig 10 7

Fig 10 6 —Three large cavities in the right lung
An indication for pneumonectomy to be followed by a partial thoracoplasty

Fig 10 7 —Tuberculous pyo-pneumothorax associated with total atelectasis after artificial pneumothorax
An indication for pleuro pneumonectomy

is most frequently seen when artificial pneumothorax has been followed by atelectasis fluid formation and bronchiectasis in an unexpandable lung Pleuro-pneumonectomy is the procedure adopted in dealing with this formidable problem, the parietal pleura being removed together with the lung (see p 257).

(d) *The failed thoracoplasty* If a well-executed thoracoplasty with apicolysis has failed to close an upper lobe cavity it is reasonable to presume that the lesion is one that will not heal by relaxation methods This important group of failures represents about 15 per cent of all thoracoplasties In retrospect these patients usually had large chronic cavities or were associated with atelectasis and perhaps represent the results of bad selection Many of these failures are now being retrieved by resections carried out beneath the thoracoplasty and undoubtedly represent a strong indication for excisional surgery

Lesions that may be suitable for resection or collapse methods or a combination of both

The indications for resection already discussed are generally acceptable. The main field for argument as to the place for excision is when this is advised as the primary method in the treatment of cavities. Here again opinions almost universally favour lobectomy or segmental resection for lower lobe cavities that have not closed after phrenic interruption, pneumo peritoneum or pneumothorax used commonly as combined methods and when conditions elsewhere in the lung fields do not provide contra indications to any form of major surgery.

The real problem is in the treatment of upper lobe cavities where thoracoplasty or resection is not contra indicated for any strong reason; both methods have a low operative



Fig. 10-8



Fig. 10-9

Fig. 10-8.—Radiographs after bilateral upper lobectomy.

A right upper thoracoplasty failed to close a cavity; after this operation a cavity developed in the left upper lobe which artificial pneumothorax failed to control and was replaced by left upper lobectomy. The right upper lobe was resected three months later.

Fig. 10-9.—An artificial pneumothorax employed for a small cavity has been followed by immediate atelectasis of the left upper lobe and enlargement of the cavity.

Immediate resection is probably safer than waiting for the pneumothorax to re-expand and substituting it by thoracoplasty, as cavity rupture and empyema might well supervene.

mortality rate. The answer must await the five year follow up of the extensive series of resections being performed all over the world at the time of writing. If resections provide over 90 per cent of patients with negative sputum its retention will be justified, for in itself it has certain attractions that are undeniable.

The psychological effect upon the patient when he knows that the disease has been actually extirpated is most valuable and supplements the physiological advantages of resection over extensive thoracoplasty. The last mentioned advantage will be great if the conservative segmental resections now being advocated by Chamberlain and Klopstock (1951) and others bear the test of time.

If, however, upper lobe cavities are associated with doubtful lower lobe states, thoracoplasty is still probably the better operation unless the resection can be supplemented early by a thoracoplasty, for the relaxation provided by the collapse measure often enables the lower lobe to recover. An upper thoracoplasty in such circumstances, that is followed by healing of the lower lobe lesions, is infinitely preferable to total lung extirpation.

The response of early tension cavities to bed rest is probably an important guide to the selection of the operative procedure. If a tension cavity enlarges under strict bed rest or artificial pneumothorax it tends to do badly under a thoracoplasty and resection may well be indicated in such a patient.

Resection is often required for the truly atelectatic upper lobe that contains or has



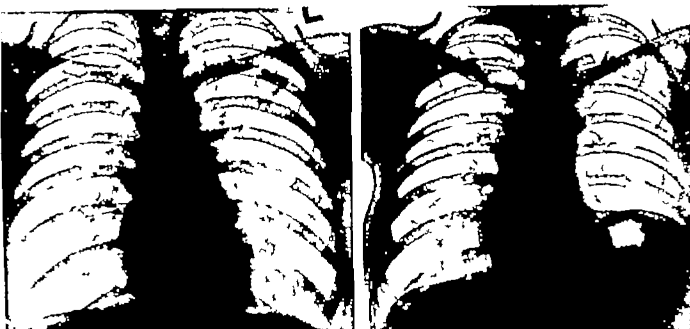
Fig. 10.10.—Collapsed upper lobe containing a chronic thick-walled cavity and bronchiectasis. Lobectomy specimen.

contained a cavity, for although thoracoplasty has been of value in the past in this type of disease its results have been erratic.

The examination of resection specimens shows that many radiological appearances, regarded as being due to fibrosis, are in fact areas of segmental atelectasis.

The types of patients mentioned above belong to a group in which resection is probably correct. Considerable difficulty still exists in patients with upper lobe cavities associated with endobronchial tuberculosis. These patients, though totally unsuitable for pneumothorax, do well with thoracoplasty in 85 per cent of instances. The immediate results of resection are excellent but relapses occur. The patient illustrated in Fig. 10.11 was a young married woman of excitable temperament; she had an obvious cavity associated with the

stigmata of endobronchial disease The physician in charge attempted a pneumothorax the upper lobe was in obvious danger of becoming atelectatic and the cavity was ballooning Thoracotomy was therefore done and the lobe resected the sputum became negative the day after operation Six months later she was in perfect health free from disease and with persistently negative sputum but 18 months later a positive sputum developed and the radiograph showed disease in the apex of the left lower lobe A small thoracoplasty was done and the sputum again became negative



(a) (b)

Fig 10-11

(a) Left upper lobe cavity with endobronchial disease in a young woman
(b) Eight months after left upper lobectomy and left phrenic nerve paralysis.

Resection is undoubtedly becoming more popular in the treatment of upper lobe cavities but it is too early to assess the results and thoracoplasty has not lost its place in the case of chronic upper lobe cavities In spite of the danger of prophecy it is probably right to say that resection will be combined with a small upper thoracoplasty in many of these patients

Resection for lower lobe cavities

Excisional surgery has removed many of the difficulties in the care of lower lobe cavitary disease the treatment of which has been discussed in the previous chapter (p 192) If bed rest phrenic nerve interruption and pneumo-peritoneum fail to close the lesion lobar or segmental resection is practised unless contra indications are provided by the state of the lung tissue elsewhere Results of excisions have been satisfactory and this addition to treatment has largely removed the pre-war pessimism that coloured the management of lower lobe disease

Emergency resections

Patients sometimes die rapidly with pulmonary tuberculosis when extensive pneumonic infiltration rupture of a cavity or haemoptysis complicate the disease Every sanatorium

physician is aware of the acute unilateral exudative disease that spares the opposite lung for several weeks such patients may respond well to bed rest and streptomycin but a few do not and resection employed boldly may save some in this group

Apart from complicating a pneumothorax, a cavity may rupture into the pleura causing spontaneous pneumothorax and then a pyo-pneumothorax Whether the catastrophe develops in the course of a therapeutic pneumothorax or is truly spontaneous the prognosis is grave, repeated aspiration and closed intercostal drainage do not always help because the large fistula from the lung into the pleura prevents re-expansion and the empyema continues These patients should be considered for emergency resection, occasionally lobectomy will suffice but more commonly a pneumonectomy is required

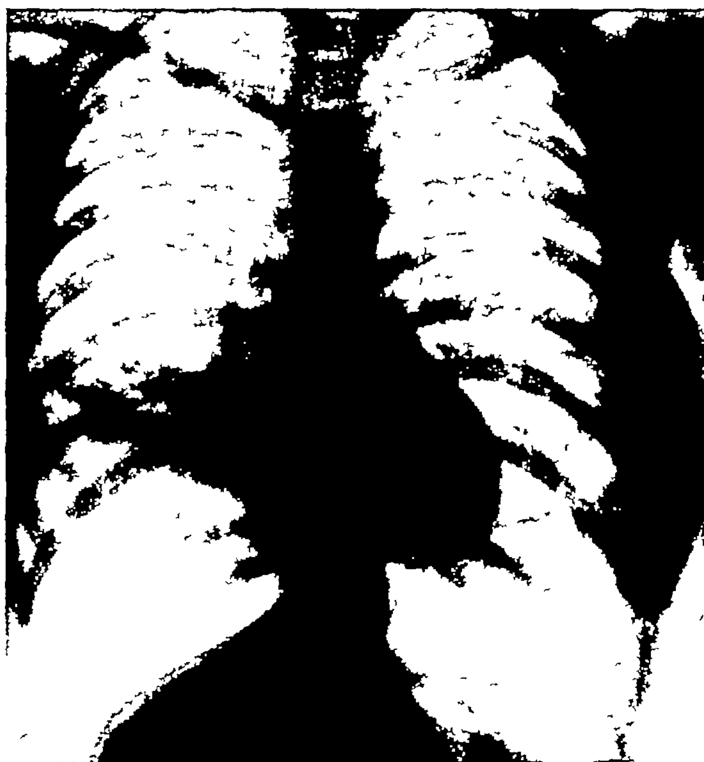


FIG 10 12—Right lower lobe cavity uninfluenced by phrenic nerve interruption and pneumo-peritoneum *Resection is indicated*

Uncontrollable haemoptysis is an occasional indication for resection (Fig 10 14) A young male nurse was admitted to the Queen Elizabeth Hospital after a large haemoptysis of over one pint Bed rest and sedation failed to stop the bleeding which recurred daily in spite of the exudative type of disease present, a left artificial pneumothorax was induced in the hope of saving the patient's life because of adhesions which were viewed thoracoscopically the collapse was ineffective and bleeding continued The left upper lobe was therefore resected He made an excellent recovery and a year later is well, apyrexial and sputum free The excised lobe showed early exudative tuberculosis with cavitation

Summary of the indications for resection

Listing the indications for any operation that is in the stage of development is difficult It is easier to lay down the conditions for surgery in the advanced stages of any disease and



(a)



(b)

Fig 10·13

(a) Radiograph taken two days after sudden onset of severe chest pain in a man of 24 during the night He had completed a full day's work.

From the empyema which followed a gross spontaneous pneumothorax, tubercle bacilli were recovered he was severely ill and pyrexial. An emergency pneumonectomy was carried out

(b) After pneumonectomy

The space was later obliterated by thoracoplasty (Dr T Lloyd patient St. Wulstan's Hospital)



(a)



(b)

Fig 10·14

(a) Ineffective left pneumothorax for exudative tuberculosis causing gross haemoptysis.
(b) Six weeks after left upper lobectomy

pulmonary tuberculosis is no exception, certain indications being established while others are still speculative

The established indications

(1) Gross unilateral disease total bronchiectasis usually with broncho-stenosis and the destroyed lung if these states are combined with empyema the extirpation should be in the nature of a pleuro-pneumonectomy (Sarot, 1949)

(2) Lobar bronchiectasis associated with the expectoration of tuberculous sputum

(3) The nodular caseous mass, "tuberculoma", or blocked cavity

(4) Cavities uncollapsed by good thoracoplasty

(5) Lower lobe cavities that do not close under the lesser measures of phrenic nerve interruption, pneumo-peritoneum or pneumothorax

(6) Most giant cavities and chronic multiple cavities in one lobe

(7) As an emergency measure for cavities that have ruptured into an established pneumothorax or have been the rare cause of a spontaneous pneumothorax that rapidly proceeds to empyema formation

The applicability of these indications to the individual must depend on the general state and the degree of tuberculous disease elsewhere in the lungs

The speculative indications

(1) Upper lobe cavities with a considerable element of bronchial disease sufficient to cause atelectasis Although thoracoplasty may close these the results are doubtful in 15 per cent of them

(2) Upper lobe cavities without much surrounding parenchymal disease In this group upper thoracoplasty is probably the better treatment, its results are excellent with a 95 per cent sputum conversion rate, if it fails the 5 per cent group can be treated later by resection without any grave disadvantage to the patient

(3) Some instances of severe haemoptysis uncontrolled by the usual conservative measures

(4) Unilateral exudative disease that is clearly failing to regress under bed rest and streptomycin

The extent of resection

As tuberculous disease often spreads across interlobar fissures lobectomy and segmental resection may involve cutting across tuberculous tissue, with possible resultant complications Ideally the resection should ablate the disease without transection of tuberculous tissue For this reason an extrapleural dissection is desirable when the diseased lung tissue is adherent to the parietal pleura, to avoid or lessen the risks of contaminating the pleural cavity when the lung, in the presence of a total empyema, is being resected by pleuro-pneumonectomy

Often the conservation of as much lung tissue as possible is desirable and lobectomy or the removal of a segment containing a cavity is obviously preferable to pneumonectomy

Excisions of tuberculous tissue are not comparable to those required in cancer surgery and the natural tendency for this disease to heal when local and general conditions are placed on a satisfactory basis should not be overlooked In this context streptomycin has considerable claims and its use is of proven value (Bailey *et al*, 1949)

The chief indications for lobectomy are "tuberculoma", lower lobe cavities that remain patent after the orthodox measures of phrenic interruption followed by pneumo-

peritoneum and possibly artificial pneumothorax especially when as is often the case the upper lobe is free from disease and upper lobe cavities persisting under a well-executed thoracoplasty for lobar atelectasis

Pneumonectomy or pleuro pneumonectomy is required for extensive bronchiectasis following broncho-stenosis for destroyed lungs and for certain examples of tuberculous pyo-pneumothorax associated with gross pulmonary disease involving both lobes

The indications for segmental resection

If segmental resections can remove safely the main tuberculous focus the physiological results are obviously better and the early experience of Chamberlain and Klopstock (1950) Overholt (1950) and Edwards (1950) are encouraging In spite of the transgression of tuberculous tissue in these limited operations the post-operative incidence of broncho pleural fistula and empyema has been surprisingly small (6 in 250 operations—Chamberlain and Klopstock 1950) If this operation is to be used there must be firm evidence that the patient has had or has the capacity of healing any small foci in the same or opposite lung this includes general and haematological evidence of good resistance and the availability of a series of films showing the natural trend of the disease in the previous months of sanatorium treatment

The segments most amenable to resection are the apical ones of the lower lobes (these may require resection together with an upper lobectomy for cavitary disease because nowhere else is trans fissural spread so common as at the superior end of the great oblique fissure) and the apical and posterior (posterolateral) segments of the upper lobe

The technique of the resection must be meticulous and the principles are those that govern the procedure as adopted in the surgery of bronchiectasis (see pp 10 174) namely precise isolation of the arterial venous and bronchial channels clamps on the tissues that are to be left are avoided and no extensive suturing of the raw surfaces of the adjacent segments is practised Since the resected segment is usually atelectatic the neighbouring lung tissue has already undergone inflating emphysema and the space is rapidly obliterated

Because it minimizes the sacrifice of healthy lung tissue segmental resection has a particular place in the treatment of bilateral tuberculosis of limited extent

A description of the anatomical approach to the various segments has been given in Chapter 1

Should thoracoplasty or phrenic paralysis with pneumo-peritoneum be employed after resection operation or before?

After resection of a lobe or lung there are two apparently clamant reasons for thoracoplasty (*a*) the thoracic cavity should be lessened in size to prevent over-distension of the good lung and in the case of lobectomy of the remaining lobe especially if the latter shows any signs of tuberculous disease however quiescent it may be (*b*) if there is a residual pleural space either a total pneumothorax or a localized pneumothorax this carries a risk of infection The late slow development of an insidious empyema after total pneumonectomy is a well recognized condition.

In most patients in whom the upper lobe has been resected the wisest course to adopt is a modified upper thoracoplasty in which the first rib may be left in place but in which the second third fourth and fifth ribs are resected in one stage this is sufficient to decrease the risk of over inflation of the lower lobe

A lobectomy may be substituted for the second stage of a planned upper thoracoplasty since the results of upper thoracoplasty for certain cavities remain problematical until the

apex of the pleura has been released, the first stage of a thoracoplasty is perform Semb's mobilization procedure If the post-operative radiograph suggests that this relaxation has not really influenced the size of the cavity, at the second stage after the rib has been resected, the pleural cavity is opened and the upper lobe removed



FIG 10 15—Thoracoplasty after left pleuro-pneumonectomy for tuberculous empyema associated with destroyed lung

Bickford and others (1951) have shown the good results that can be achieved in de ing the size of the hemithorax after resections by phrenic nerve paralysis and pn peritoneum if the diaphragm can be kept well elevated for 8–12 weeks after the res If it is maintained at an abnormally high level for this period it usually remains permanently and the need for thoracoplasty may be avoided

Some technical considerations in resection for tuberculous bronchiecta

The usual pre-operative measures include the administration of streptomycin for s days before operation The anaesthetic problems are those for bronchiectasis in ge the Thompson blocker is useful for pneumonectomy patients to allow smooth anaes by avoiding the blocking of the airway by sputum and to lessen the post-operative r spread of tuberculous disease to the sound side Occasionally tuberculous granu tissue may be present almost up to the carina and then the blocker cannot be used, c post-operative bronchoscopic aspiration is indicated

During the course of lobectomy or pneumonectomy cutting into tuberculous tissue be avoided as far as possible Where the lung is densely adherent to the parietal pleu dissection is carried widely into the extrapleural plane This extrapleural dissection be the cause of considerable blood loss and the transfusion requirements must be

promptly The dissection of vessels and bronchi is more difficult than in cases of bronchiectasis or carcinoma because of the obliterative effect of tuberculous disease on tissue planes and the production of dense fibrous reactions

The bronchus, main or lobar is sectioned as close to the trachea or main stem bronchus as possible a long stump increases the risks of fistulous formation but a small fringe of bronchial tissue should be left in upper lobectomy to avoid the need for placing sutures in the right cartilaginous framework of the main bronchus For the reason given elsewhere (p 282) the open bronchus technique is used Technical and anatomical details concerning pneumonectomy lobectomy and segmental resection are given in Chapters 1 12 and 8

Streptomycin should be left in the pleural cavity at the close of the operation If the resection has been lobar or segmental the chest is drained for 24–48 hours but it is closed without drainage after a total pneumonectomy, the pressures being adjusted and left slightly positive at the close of the operation

The question of closing the space by thoracoplasty or by pneumo peritoneum has been discussed (p 241) The decision to avoid thoracoplasty has been based on humanitarian rather than scientific reasons but usually it should be advised after total pneumonectomy Such a post-pneumonectomy thoracoplasty may be a limited one the first rib being spared and generous segments of the second third fourth fifth six and seventh ribs being resected.

DIRECT CAVITY DRAINAGE

Attempts to cure tuberculous cavities by drainage have not been very successful or widely adopted A persistent tension cavity should close on theoretical grounds if the intracavitary pressure can be reduced and the draining bronchial opening either completely obstructed or opened so that the features of a valve mechanism disappear When the air in the cavity is under high pressure its walls have a poor blood supply which interferes with the natural processes of healing Coryllos (1939) studied this problem extensively In differentiating the thin walled distension cavity from the one with thick walls not only did he point to the clinical differences in that the first group are often in better health with few bacilli in the sputum but that pressure in the tension cavity is estimated as greater than atmospheric The air is entrapped in the cavity because of the valvular mechanism provided by endobronchial disease in the draining bronchus On theoretical grounds the cavity will close if the bronchus becomes completely blocked so that the enclosed air is absorbed and the surrounding lung parenchyma distends to complete the cavity obliteration if the bronchus remains partially opened closure should follow the removal of intracavitary tension by open or closed drainage

The drainage of cavities can be performed by the closed or the open method

Closed external intermittent drainage method of Monaldi

At Monaldi s clinic cavities have closed and remained closed for many years after his method has been employed the same results have not been achieved elsewhere By this treatment many cavities have decreased or temporarily disappeared but permanent closure without the use of thoracoplasty has been all too rare

By means of a small specially constructed catheter intermittent drainage of the cavity is possible The method cannot be used across a free pleura as the risk of empyema development would be formidable If careful exploratory punctures with the artificial pneumo

thorax apparatus reveal a free space, pleurodesis is achieved by chemical agents of which the best is 10 per cent silver nitrate solution The special trocar and cannula are introduced through the anaesthetized skin and pleura into the cavity which has been localized by careful X-ray study Monaldi introduces the instrument under direct X-ray vision with remarkable rapidity and dexterity When the cannula is in the cavity the trocar is partially withdrawn and the pressures estimated by connecting the hollow cannula through a specially made lateral metal side opening to the artificial pneumothorax apparatus manometer The catheter is then passed through the cannula into the cavity sufficiently far to coil up within it The cannula is withdrawn and at set periods in the day a suction pressure is applied to it in Monaldi's clinic this is achieved simply by using two artificial pneumothorax bottles arranged to produce a gentle suction If continuous suction is applied, as it so often is in this country by a Roberts suction motor, the bronchial opening will be kept partially patent and the object of the treatment antagonized The tube requires constant attention to keep it patent

The cavity usually decreases in size and tubercle bacilli may disappear but permanent closure is rare, if the cavity is an upper lobe one, thoracoplasty with apicolysis should be performed as soon as radiological studies show that maximum shrinkage has occurred The thoracoplasty will be a little hampered because of the presence anteriorly of the cavity fistula

The catheter should be introduced into the cavity through the second intercostal space as near to the sternum as is safe and practicable Holmes Sellors used to resect the front ends of the first and second ribs before introducing the catheter into the cavity so that this area need not be transgressed at the subsequent thoracoplasty, performed through the usual posterior incision

Open cavity drainage (speliotomy)

In this method the cavity wall is thoroughly exposed and through the adherent overlying pleura a wide opening is made Perhaps the chief indication is after a good thoracoplasty has failed to close the cavity its use might be justifiable for large tension cavities when thoracoplasty, for a variety of reasons, is contra-indicated It has a small but strictly limited field of application and has been largely replaced by resection operations

The operation is usually conducted under local anaesthesia after exact radiological localization of the cavity In the upper lobe, especially after thoracoplasty, the cavity will be sited close to the spine and its exposure and opening may be difficult The overlying intact or regenerated ribs are resected and the presence of the cavity demonstrated by inserting a large-bore needle mounted on a syringe with a little fluid in it when the plunger is withdrawn air from the cavity will bubble into the syringe A wide area of the cavity wall is removed by diathermy and the space gently packed with gauze as the cavity will require packing for a long time over many months, the walls of the wound leading down to the cavity must be widely exposed, otherwise great difficulty will be experienced in the dressings the gauze may be steeped in a streptomycin solution

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CHAPTER 11

TUBERCULOUS DISEASE OF THE PLEURA AND CHEST WALL

PLEURAL EFFUSION

Primary effusions

These, though tuberculous in most instances, do not arise as a complication of established pulmonary disease, though they accompany or may follow a primary complex on the same or opposite side. They are easy to diagnose and simple to treat, their chief significance being that nearly one-fifth of the patients with primary effusions develop obvious tuberculous lesions on the same or the opposite side within five years. Many patients in recent years have passed from a Mantoux negative stage to a primary infection



FIG. 11.1.—A long-standing tuberculous empyema which followed a primary effusion

which has rapidly become complicated by a pleural effusion (Thompson, 1949). Primary effusions usually absorb spontaneously; aspiration is required for diagnostic purposes, for the relief of dyspnoea and to aid absorption if this is too slow. If all effusions are left to subside spontaneously by too simple a faith in rule of thumb methods an occasional patient is left with a compressed, contracted lung and a flattened immobile chest wall with a highly placed rigid diaphragm, and the loss of respiratory function may be a high price to pay for the over-studious application of the principles of rest.

In modern practice there is no place for aspiration with air replacement in primary effusions, simple paracentesis only being practised when fluid removal is indicated. Bed

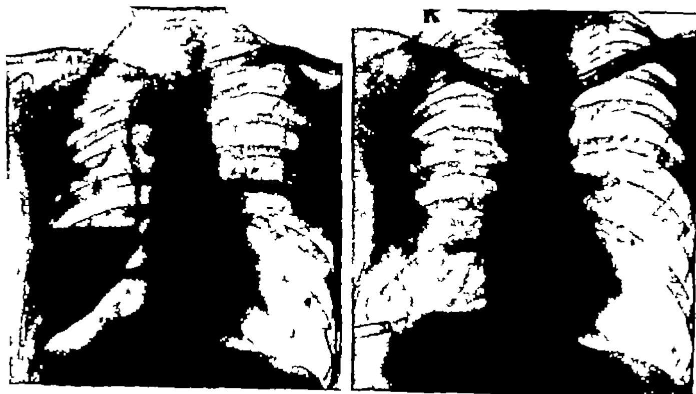
rest should be for a minimum of three months phrenic nerve crush may be required for persistent pain in the base of the chest associated with referred shoulder tip pain

Exceptionally the effusion progresses to empyema The tubercle bacilli persist the cell content rises and the fluid becomes turbid. With this development the blood sedimentation rate which falls rapidly when a pleural effusion absorbs under the influence of complete bed rest remains raised The occasional empyema that follows a primary effusion presents difficulties if the lung fails to re-expand a chronic empyema results and with a persistence in conservative treatment the patient slowly deteriorates although survival for many years with such an empyema is well recognized Aspiration will often result in lung re-expansion and must be practised thoroughly but if it fails the obliteration of the empyema space by thoracoplasty should not be deferred too long because of the progressive pleural thickening operative measures if delayed unduly will fail to secure parietal and visceral symphysis

Excision of the empyema or decortication should be practised if the underlying lung is in reasonably good condition The empyema sac can be removed in its entirety in a surprisingly high portion of cases (Sarot 1949)

Secondary effusion

This may arise spontaneously during the course of post-primary tuberculosis more usually it is a complication of an unsatisfactory artificial pneumothorax It may be excited



(a) (b)

Fig 11 —Radiographs of a male adult with pulmonary tuberculosis (*a*) complicated by a spontaneous pyo-pneumothorax (*b*) satisfactory lung re-expansion after drainage

by the development of tubercles on the parietal and visceral pleura from repeated trauma to adhesions during the phases of respiration or as a complication of collapse of a lobe within the pneumothorax space

A persistent effusion is not unusual after a spontaneous pneumothorax of tuberculous etiology or after a lung air leak into a pre-existing pneumothorax space. A traumatic effusion after the division of adhesions or after thoracotomy for lobectomy, segmental resection or pneumonectomy is common, but rarely passes on to empyema formation unless a gross complication such as broncho-pleural fistula complicates the operations. Thorough aspiration will be required for the post-operative effusions and streptomycin may be left in the pleura as a prophylactic measure.

Effusions following an artificial pneumothorax may be of negligible or serious significance. In the early stages of satisfactory artificial pneumothorax a little fluid may collect in the costo-phrenic angle or even cover part of the curve of the diaphragm. Such effusions should be aspirated and examined for the presence or absence of tubercle bacilli: if no bacilli are found and the effusion does not recur the pneumothorax may be continued with safety, but obvious tuberculous infection and a tendency to rapid re-accumulation of fluid after aspiration is an indication for abandoning the pneumothorax, especially if the cell content of the fluid is high. This type of effusion is usually seen only when the pneumothorax is unsatisfactory and atelectasis or indivisible adhesions are present. The prompt re-expansion of such a lung will avoid the dangers of an empyema developing.

Tuberculous empyema

Opaque pleural fluid containing a high cell count, a protein content higher than that of a serous transudate and tubercle bacilli is regarded as empyematous; when secondary infection, usually the result of a broncho-pleural fistula, is superimposed, the tubercle bacilli may disappear. Most tuberculous empyemata are a complication of artificial pneumothorax treatment; scrupulous attention to the indications and contra-indications to this form of therapy has greatly diminished its incidence, which should not exceed 1 per cent.

Natural history of the disease

In a pneumothorax rendered unsatisfactory and dangerous because of indivisible adhesions, of contra-selectivity or lobar atelectasis a serous effusion is a common natural sequel. The fluid slowly becomes turbid and purulent, especially if tubercle bacilli have been discovered while it was still thin and serous. Tuberculous pus formation will be rapid when pleural infection follows the rupture of a cavity into the pneumothorax space or the tearing away of the lung attachment of an adhesion (Simmonds, 1941). Simmonds stressed the importance of cavity rupture as a cause of empyema. The empyema, once developed, is a greater menace to life than the original lung lesion for which the artificial pneumothorax was selected. Recorded mortality rate figures are usually about 40 per cent. Brock (1943) reported 44 per cent deaths in 90 cases. Woodruff (1938) found a mortality of 42 per cent in 154 cases. Alexander (1937) collected 779 patients from different published articles and found a *mortality rate of 41.6 per cent.*

Seventy-four patients with tuberculous empyema were studied at Semb's Clinic in Oslo between 1941 and 1947; a follow-up of these in 1948 showed that 25 had died (Andersen, 1949). These figures are not much more encouraging than a mortality rate of 58.2 per cent in 79 cases reported by A. Brian Taylor in 1932. The high mortality rate is the best reminder of the seriousness of the condition and all personal experiences and published papers incriminate a bad artificial pneumothorax as the usual cause.

Siddons and Konstam (1951) have recently published a far better survival rate in 61 cases of tuberculous empyema and had only 4 deaths, the lowest death rate I can find in the literature; 55 of their patients represented complication of artificial pneumothorax

Once a tuberculous empyema has developed the course of the disease is downhill in most cases because of the increase of toxaemia the result of absorption from the large pleural surface the incidence of secondary pyogenic infection due to pleural fistula or massive atelectasis and the increased risks of contra lateral spread. In addition there is a progressive loss of respiratory function the result frequently of an unexpandable lung and crippling of the chest wall. In long persisting disease amyloidosis may develop The outlook is specially gloomy if the pneumothorax has failed to control a parenchymal lesion of cavernous nature A review of the earlier radiographs in this type of empyema often revealed a cavity that would have been treated preferably by a primary thoracoplasty

If the lung does not re-expand fluid re accumulates in spite of careful aspiration a thick fibrinous envelope later to be organized into dense fibrous tissue develops on the visceral and parietal pleura The strangling effect of this fibrous layer on the lung further impedes the chance of the lung becoming adherent to the parietes and indicates that efficient treatment often consists of decortication or thoracoplasty If thoracoplasty is deferred too late however drastically and thoroughly it may be executed complete obliteration of the infected pleural space may not be achieved

Secondarily infected tuberculous empyema

Many tuberculous empyemata follow the rupture of a small tuberculous lung focus that is peripheral and sub-pleural and without a large bronchial opening Larger foci or actual cavities that break down give rise to broncho-pleural fistulae which carry the grave risks of a complicating secondary pyogenic infection This major catastrophe is accompanied by a dramatic clinical deterioration illustrated by a sudden malaise a high temperature and loss of appetite this is usually followed by the expectoration of large quantities of pus the other lung remains in constant danger of an acute bronchogenic spread of disease The treatment of this grave complication must be thorough and prompt and drainage or even such major procedures as resection of the lung may be required

All secondarily infected empyemata should be assumed to be associated with a fistula the gravity of secondary infection is reflected in a mortality rate of 90 per cent in those patients who are not fit enough to undergo thoracoplasty or more recently pleuro pneumonectomy (Sarot 1949)

Treatment

This may be (*a*) prophylactic (*b*) conservative (c) surgical

(*a*) Prophylactic treatment Since unsatisfactory artificial pneumothorax is the commonest cause of empyema the selection of patients for a treatment of such potential danger must be scrupulous Patients with tension apical cavities atelectasis endobronchial tuberculous disease and exudative disease are not suitable for pneumothorax induction a pneumothorax unsatisfactory because of contra selective collapse atelectasis or the presence of indivisible adhesions should be abandoned for other and less dangerous forms of treatment Transient effusions in an otherwise satisfactory pneumothorax or following the division of adhesions should be aspirated their persistence should be viewed with suspicious anxiety that often leads to abandonment

(*b*) Conservative treatment Ineffective therapy is indicated in the literature by a multitude of suggested systems often of great complexity They are rarely in use today The aim of conservative treatment is the *same as* that attempted surgically namely the obliteration of the pleural space If a *pleural* effusion potentially purulent or a true

empyema is developing, every effort is made to secure lung re-expansion, the fluid is aspirated and antibiotics used to sterilize its contents. The techniques of air replacement, by which it is hoped to maintain the pneumothorax and at the same time remove the purulent fluid, are based largely on a faulty conception of the etiology of the complication which lies essentially in the underlying ineffectiveness of the pneumothorax. Certainly no case can be made out for the method if the lung is atelectatic either in all or one lobe, or if a tension cavity or endobronchial diseases co-exist.

Before embarking on the medical treatment of tuberculous empyema by aspiration, pleural lavage or the instillation of antiseptics or antibiotics, the ultimate aims and hopes must be clearly considered. If the pneumothorax, now complicated by effusions or empyema, has failed to control the underlying disease in the lung, neither condition will be cured by conservative measures.

The best chance of recovery depends on major surgical measures, provided the other lung is sufficiently stable. In such patients aspirations and intrapleural chemotherapy are useful preparatory measures which must not be used too long because delay may lead to multiple cutaneous fistulae through the aspiration sites or encourage such thickening of the pleura that even the most radical thoracoplasty will fail to close the pleural space.

In patients with a favourably controlled lung lesion within the infected pleural space, early aspiration with lavage may control the infection and enable a satisfactory pneumothorax to be maintained, though this is quite exceptional. The important measures in such patients include complete bed rest and repeated aspirations under radiological control. The aspiration sites should be so selected that if they become infected this will not interfere with the plan for later thoracoplasty. If the fluid is too thick for needle aspiration the use of a thoracoscopy cannula placed high up anteriorly may enable a suction tube to aspirate all the thick products in the lower pleural cavity. Thorough aspiration is the key to success and exceeds in importance the use of any sterilizing solution, though streptomycin and para-aminosalicylic acid placed intrapleurally are of value.

For lavage, solutions of normal saline or azo-chloramid (1 in 2,000) may be selected from a host of solutions that have been used.

Siddons and Konstam (1951) have recorded satisfactory results of aspiration in the treatment of empyema uncomplicated by patent cavities and a persistent broncho-pleural fistula. Their results are due to excellent technique in aspiration which is thorough and aided by the study of the levels and depths of the effusions as seen on radiographs taken a day after the injection of radio-opaque oil into the pleural cavity. They emphasize the need for thoroughness in aspiration and for the immediate adoption of major surgical measures when the contra-indication to aspiration treatment exists (patent cavities, persistent fistulae, inexpandable lungs).

Oleo-thorax. The filling of the pleural cavity by oily solutions such as Gomonol in cotton seed oil or olive oil has a very limited application; it has no sterilizing value but is employed solely for its space-occupying function. It should only be placed in a pneumothorax space no longer showing signs of active pleuritis; it is contra-indicated in secondarily infected pneumothoraces which have, or have had, broncho-pleural fistulae entering them and the introduction of oil usually leads to its distressing expectoration.

The grave risks of oleo-thorax are recurrence of empyema and the production of broncho-pleural fistulae; it produces a permanent degree of collapse but without the safety of a permanent thoracoplasty. If oleo-thorax is practised the pleural cavity should be amply filled with the oil for a partial oleo-thorax is valueless. The surgical antipathy to oleo-thorax may be based on the fact that only the gross failures of its application reach surgical

centres but in the years of its popular use many distressing examples of pyo-pneumothorax with fistula formation were seen I have no personal experience of this method of treatment

(c) **Surgical treatment** The surgical aims in the treatment of tuberculous empyema are the same as in the management of pyogenic empyema namely the removal of pus and the obliteration of the pleural pocket In tuberculous empyema the chief difficulty is to obtain expansion of a lung that is actively diseased or has suffered great loss of elastic tissue as the result of the fibrotic healing of disease or secondary to the stenotic healing of a tuberculous endobronchitis Moreover the lung may contain a focus that constantly re-infects the pleural cavity either through a fistula or a ruptured cavity or from an infected collapsed lobe or lung This latter condition may be compared with the empyema that may complicate a permanently collapsed upper lobe after a lobectomy for basal bronchiectasis the cure of which will entail a residual lobectomy

The removal of the empyema fluid For the simple pure tuberculous empyema needle aspiration is employed before and during thoracoplastic procedures and surgical drainage is avoided as far as possible In secondarily infected pyo-pneumothorax however inter costal drainage may be required to save life and the toxaemia from the suddenly flooded pleural cavity resembles that seen in putrid empyema the result of a ruptured lung abscess

The site of drainage should be selected with the thought in mind that later a thoraco-plasty or a lung resection operation will be required and the drainage must be of the water sealed variety to encourage lung re-expansion as much as possible Occasionally this drainage will be followed by lung re-expansion and obliteration of the pleural space but this happy result is a rarity

Major surgical measures for tuberculous empyema

The obliteration of the total pyo pneumothorax space is hindered by a grossly thickened parietal pleura and a collapsed lung so that a residual space is often left even after a most radical thoracoplasty of four or five stages including anterolateral as well as extensive posterolateral rib resections Especially distressing at the end of these *major interventions* is the persistence of a drained empyema space which may necessitate a permanent tube These extensive thoracoplasties have been largely superseded by the use of pleuro-pneumonectomy

A complete achievement of pleural symphysis is far more likely if the *thoracoplasty* is commenced as soon as the patient is fit for operation It is unwise to persist too long in efforts aimed at securing lung re-expansion by repeated aspiration or closed drainage for the delay often produces an unnecessarily thickened pleura that will not collapse after the most extreme rib resection If for good reasons the delay has been inevitable *total* obliteration may only be possible by combining the thoracoplasty with a pleural decortica tion or by the use of Roberts s operation of turning in a large flap containing parietal pleura and intercostal bundles which has been fashioned by anterior superior and inferior incisions into the roof of the empyema the whole being hinged on its posterior attachment It is sometimes advantageous to divide the musculo pleural flap posteriorly instead of in front (W P Cleland) If the residual cavity is of moderate size it may be opened widely from its apex to its base and treated by packing in the hope of cure by eventual cicatrization of granulation tissue

If the underlying lung contains a large fistula or has residual cavitation total excision of the lung and infected pleura (pleuro-pneumonectomy) is far more effective and has

empyema is developing, every effort is made to secure lung re-expansion, the fluid is aspirated and antibiotics used to sterilize its contents. The techniques of air replacement by which it is hoped to maintain the pneumothorax and at the same time remove the purulent fluid, are based largely on a faulty conception of the etiology of the complication which lies essentially in the underlying ineffectiveness of the pneumothorax Certainly no case can be made out for the method if the lung is atelectatic either in all or one lobe, or if a tension cavity or endobronchial diseases co-exist

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(*c*) **Surgical treatment** The surgical aims in the treatment of tuberculous empyema are the same as in the management of pyogenic empyema namely the removal of pus and the obliteration of the pleural pocket In tuberculous empyema the chief difficulty is to obtain expansion of a lung that is actively diseased or has suffered great loss of elastic tissue as the result of the fibrotic healing of disease or secondary to the stenotic healing of a tuberculous endobronchitis Moreover the lung may contain a focus that constantly re infects the pleural cavity either through a fistula or a ruptured cavity or from an infected collapsed lobe or lung This latter condition may be compared with the empyema that may complicate a permanently collapsed upper lobe after a lobectomy for basal bronchiectasis the cure of which will entail a residual lobectomy

The removal of the empyema fluid For the simple pure tuberculous empyema needle aspiration is employed before and during thoracoplastic procedures and surgical drainage is avoided as far as possible In secondarily infected pyo-pneumothorax however inter costal drainage may be required to save life and the toxaemia from the suddenly flooded pleural cavity resembles that seen in putrid empyema the result of a ruptured lung abscess

The site of drainage should be selected with the thought in mind that later a thoraco-plasty or a lung resection operation will be required and the drainage must be of the water sealed variety to encourage lung re-expansion as much as possible Occasionally this drainage will be followed by lung re-expansion and obliteration of the pleural space but this happy result is a rarity

Major surgical measures for tuberculous empyema

The obliteration of the total pyo pneumothorax space is hindered by a grossly thickened parietal pleura and a collapsed lung so that a residual space is often left even after a most radical thoracoplasty of four or five stages including anterolateral as well as extensive posterolateral rib resections Especially distressing at the end of these major interventions is the persistence of a drained empyema space which may necessitate a permanent tube These extensive thoracoplasties have been largely superseded by the use of pleuro pneumonectomy

A complete achievement of pleural symphysis is far more likely if the thoracoplasty is commenced as soon as the patient is fit for operation It is unwise to persist too long in efforts aimed at securing lung re-expansion by repeated aspiration or closed drainage for the delay often produces an unnecessarily thickened pleura that will not collapse after the most extreme rib resection If for good reasons the delay has been inevitable total obliteration may only be possible by combining the thoracoplasty with a pleural decortica tion or by the use of Roberts s operation of turning in a large flap containing parietal pleura and intercostal bundles which has been fashioned by anterior superior and inferior incisions into the roof of the empyema the whole being hinged on its posterior attachment It is sometimes advantageous to divide the musculo-pleural flap posteriorly instead of in front (W P Cleland) If the residual cavity is of moderate size it may be opened widely from its apex to its base and treated by packing in the hope of cure by eventual cicatrization of granulation tissue

If the underlying lung contains a large fistula or has residual cavitation total excision of the lung and infected pleura (pleuro pneumonectomy) is far more effective and has

largely replaced thoracoplasty In favourable cases the resection may be confined to a lobectomy followed by a partial thoracoplasty after the remaining lobe has been decorticated

Thoracoplasty

Preparation of the patients by aspiration and not drainage is the aim in tuberculous empyemata , the secondarily infected patients usually will have been drained The general condition of these patients is often poor and amyloid disease may have commenced , it is important not to regard this as a contra-indication, for there is evidence that the process is reversible if the infection is eradicated or controlled and the onset of this degeneration is indeed an indication for urgent major surgery It hardly ever occurs in the absence of tuberculous infection, being seen most commonly in the chronic secondarily infected pyo-pneumothorax

The pre-operative measures include attention to the state of the blood picture and to the improvement of the usual hypoproteinaemia , the full pre-operative course of nutritional therapy is adopted

Anaesthesia and posture on the table Local anaesthesia is advisable if the thoracoplasty is being done at a comparatively early stage of empyema formation, but will be replaced by general anaesthesia when chronicity has caused great thickening of the parietal pleura with overlapping of the ribs, for this combination prevents efficient local anaesthesia and creates special surgical difficulties which militate against gentle stripping and elevation of the ribs

If a broncho-pleural fistula is present the usual posterolateral position places the sound underlying lung in great peril from the risk of spill-over infection , in a patient with a totally collapsed lung the danger may be overcome by the use of Thompson's blocker but the prone position or one in which the patient is propped up high in the anti-Trendelenburg position is usually the best answer to the difficulty

The operation The amount of rib to be resected must be extensive and staging of the operation is essential to avoid severe surgical shock At the first stage the first three or four ribs are removed sub-periosteally from the level of the transverse process to the cartilages If the empyema space reaches to the clavicle or higher the performance of a Semb's extrafascial apicolysis has great merit and facilitates the start of pleural symphysis the result may be so satisfactory that frequently it enables a stage to be avoided, as the dropping of the pleural dome does much to decrease the size of the empyema The extrafascial fibro-muscular bands are greatly hypertrophied, evidence of the part they play in maintaining elevation of the apex of the empyema pocket If a cavity is present in the apex of the lung the addition of this apicolysis is an essential step

The later stage of the operation involves a resection of ribs, greater in extent than that required in thoracoplasty for parenchymal disease Fortunately there is rarely trouble from paradoxical respiration because of the rigidity of the pleura and the mediastinum

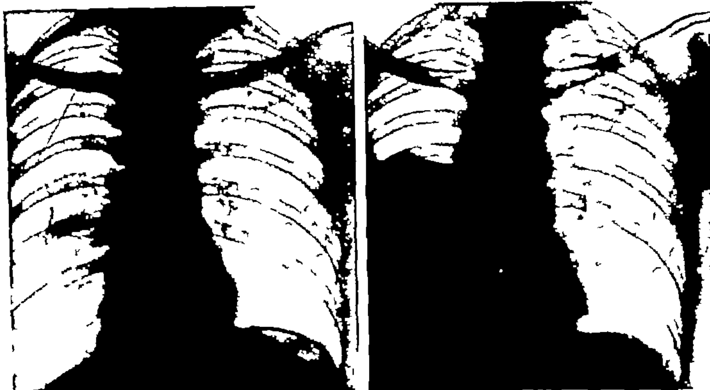
The addition of an anterolateral stage is indicated if two weeks after the completion of a radical posterolateral thoracoplasty the radiograph reveals a cavity that is not rapidly closing If this stage is delayed too long the regeneration of the ribs excised at the first and second stages will prevent further adequate collapse

Decortication

Excision of the thickened visceral pleura enveloping the lung in chronic non-tuberculous empyema has been practised for many years (Delorme, Ransohoff Hedblom) and it has been applied to tuberculous empyema more recently because of the disappointments after

many extrapleural thoracoplasties and because a successful result by this method is achieved with less mutilation and deformity and possibly with some improvement in lung function

(1) Decortication alone is the operation of choice for an unexpandable lung in which limited disease had healed under a pneumothorax that unexpectedly became complicated by an effusion which though readily controlled by aspiration led to a progressive deposit of fibrin on the pleura If full re-expansion can be obtained as is usual by a single operation without re activation of disease the advantages over a full thoracoplasty are obvious



(a) (b)

FIG 113

(a) A long standing right pneumothorax of 8 years
Upper lobe could not re-expand. Left phrenic evulsion had been performed for left apical disease
(b) Spontaneous pneumothorax into right pleural cavity followed by secondarily infected pyo-pneumothorax
An indication for thoracotomy and decortication.

(2) Decortication combined with an upper partial thoracoplasty has an important place in the treatment of a tuberculous empyema that has arisen from the following set of misfortunes an artificial pneumothorax induced for upper lobe disease with correct or incorrect indications may suddenly cease to be selective if the lower lobe collapses failure to obtain re-expansion of this lower lobe by abandonment of the pneumothorax is often followed by an effusion that may proceed to pus formation The inability of the lobe to re-expand is due to its distortion and imprisonment by fibrin deposition which becomes organized into dense fibrous tissue A successful decortication followed by an upper thoracoplasty will lessen deformity save the need for multiple operations and if performed sufficiently early may restore some respiratory function to the lower lobe

(3) A third use for decortication is in combination with an upper lobectomy An ill applied artificial pneumothorax for an upper lobe tension cavity may be followed by effusion and empyema formation sometimes with rupture of the cavity The previously healthy lower lobe after decortication of its fibrinous envelope may be conserved while

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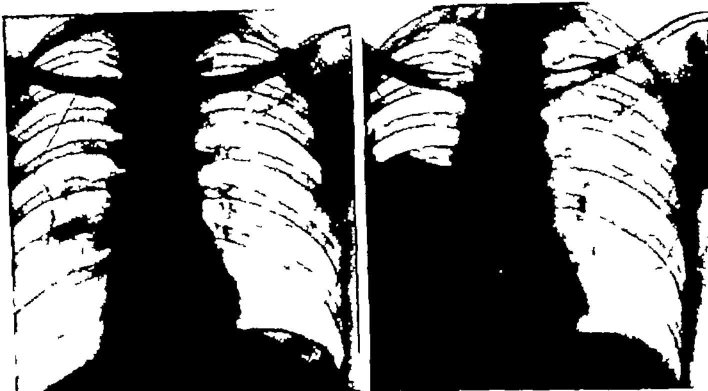
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(*a*) (*b*)

FIG. 11 3

(*a*) A long-standing right pneumothorax of 8 years. Upper lobe would not re-expand. Left phrenic avulsion had been performed for left apical disease.

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the upper lobe is resected Occasionally the re-expanded lower lobe may adequately the hemithorax without producing undue distortion of the mediastinum and the other li If, however, this is not achieved or because the other lung has been the seat of disease t may be adversely affected by over-distension, the result of a mediastinal shift to the lo tomy side, an upper thoracoplasty is indicated

(4) Decortication can be employed with success in patients with unexpandable lu of long duration who suddenly develop a pyogenic empyema

(5) A basal empyema cavity remaining at the completion of an extensive staged thora plasty may be obliterated by a partial lower lobe decortication in preference to a myopla or Roberts's flap operation The aim in these operations is really the total excision of empyema through the extrapleural plane and the cavity can at times be removed with being opened

Contra-indications to decortication

(*a*) The chief obstacle to a good result is extensive disease in the collapsed lung: existence of this may be estimated radiologically, by the presence of tubercle bacilli in sputum, and the demonstration of a lung cavity by means of tomography Tuber bacilli in the pleural fluid are not a contra-indication

A lung collapsed by artificial pneumothorax does not necessarily undergo fibros after many years of passive collapse the alveoli may reopen and their blood supply a functional capacity return; the histio-cytic proliferation of the walls of the alveoli, t change in the shape of the capillary blood vessels and the increase of connective tissue the peri-vascular and peri-bronchial spaces may all return to normal structure (Vorwa A. J., quoted by Gordon and Welles, 1949)

Extensive disease of the lung undergoing pneumothorax collapse will, however, replaced by fibrous tissue and this may have destroyed the elasticity of the lung so that re-expansion will not follow and the attempt to make it do so might well re-activa tuberculous disease

(*b*) Stenosis of the main or lobar bronchus is an absolute contra-indication to decortic tion consequently no decortication should be attempted until a bronchoscopic examinati has been done

Objections to decortication

(*a*) *Risk of infection* Not easily can the reluctance to operate on tissue contamin tubercle bacilli be shed But the disastrous results which in the past followed the acc dental opening of tuberculous lung tissue do not seem to follow deliberate operations suc as Monaldi drainage or lobectomy or pneumonectomy, and the theoretical dread th extensive removal of tuberculous pleural tissue will lead to spread and re-activation disease has not been supported by the results of decortication in the treatment of pleu empyema provided active diseased areas in the lung are not opened in such a way as t provide a continual escape of bacilli It is difficult to estimate the degree of safety confer by streptomycin but most of the good results published have been from patients who hav received this drug locally and generally

(*b*) *Failure to restore function in the decorticated lung* Radiological evidence of sati factory re-expansion is no criterion of a similar return of function, this affords a disappoin ing contrast with the physiological improvements that follow decortication performed earl for the release of lungs imprisoned by a fibrinous envelope the sequel of a clotted haemo thorax or developing in a subacute pyogenic empyema; perhaps the lack of improvemen

in the respiratory physiology of a tuberculous lung that has become unexpandable after a pneumothorax is due to the underlying parenchymal disease that has been followed in the healing process by a replacement fibrosis that prevents a reversion to a more normal state Respiratory studies often show a dramatic improvement in the maximum breathing capacity in the division of lung volumes and in the arterial oxygen saturation after a satisfactory therapeutic pneumothorax has been abandoned with good lung re-expansion. The same cannot be predicted in all patients treated by decortication with a good radiological result and in some the respiratory function is actually depressed Lacking as we still do sufficient data based on the modern tests for function after decortication it is only possible to indicate the present trend of the findings In more than half of the patients treated the maximum breathing capacity shows a deterioration in a third the total lung volume shows an increase after operation but not necessarily with any improvement in ventilation But the striking disappointment is reflected in the frequent evidence of a decrease in the arterial oxygen saturation This hypoxia is accentuated when the subject is doing exercise during the investigation

The decrease in the arterial oxygen saturation may be due to one of two factors or to a combination of both With the re-expansion of the lung more blood enters it through the pulmonary artery because the channels of the arterial bed have been re-opened as a result of the re-expansion this extra blood fails to be adequately re-oxygenated either because the lung ventilation is too poor to permit an adequate arterial-oxygen exchange or because the long-continued collapse and the underlying disease has altered the character of the alveolar walls preventing the normal gaseous interchange at that level The poorly oxygen ated blood then flows through the pulmonary veins to mix with that from the sound side and the general arterial oxygen saturation is lowered

Disappointing though these physiological results may be the obliteration of a pyo pneumothorax removes far greater dangers than those likely to follow a minor degree of hypoxia and the physiological findings are not sufficient to justify the withholding of the operation with its proved benefits

The operation Pentothal curare and oxygen with controlled respiration provide satisfactory anaesthesia The positioning on the table depends on the presence or absence of a fistula and the contents of the empyema space After the fluid has been completely aspirated the chest should be opened in the head high position or in the prone Sellors Overholt position until all the pleural contents have been sucked out

A wide thoracotomy through the bed of the resected fifth or sixth rib gives good access and multiple resections are not required When the empyema space has been sucked out and mopped dry the pearly grey membrane will be seen covering and obscuring all normal anatomical structure including the lung pericardium diaphragm and the parietal pleura Between this dense opaque tissue lies a plane of cleavage between the pleura visceral or parietal which is crossed by fine vessels to expose this plane more than one exploratory incision through the rind of dense fibrous tissue may be needed before the shiny bluish pleura is seen The incisions made with a scalpel should be long when the edges of the incisions have been separated by blunt dissection they are held up on each side by several artery forceps and if the correct plane has been reached it is developed by blunt dissection carried out largely by pledglets mounted on long slightly curved artery forceps of the Tudor Edwards's type aided by the use of scissors Slight oozing of blood and frequently the escape of small bubbles of air are inevitable as the delicate communications between the peel and the pleura overlying the lung are severed If at any area this appears to be unduly evident a moist gauze pad is left there and the dissection proceeded with elsewhere

If extreme areas of adherence to the underlying lung are encountered, a circular cut round the fixed spots is made and the cicatrized patch of pleura left *in situ*: this is frequently required over the upper lobe when, as is usual, this has been the seat of disease calling for the original pneumothorax, and it is obvious that the greatest care must be exercised in the peeling of tissue from any area known to have been involved in tuberculous disease.

The decortication must be thorough and the whole lung should be mobilized and the interlobar fissures completely freed. Frequently the lower lobe will be found to be twisted so that its basal margin may be fixed to portions of lung above and anteriorly. Similarly the apex of the lower lobe is often held captive in a downwards position and it must be freed on all sides and the fissure between it and the upper lobe cleared.

Once an adequate stripping has been secured it is a great help to have the lung re-inflated by the anaesthetist and this assists in the further dissection while the edges of the "peel" to be removed are held upwards. Any linear tear in the lung tissue is repaired by fine silk or cotton sutures and fibrin foam or fine layers of oxycel gauze are useful adjuncts in checking undue oozing. The lower lobe must be freed completely from the diaphragm which itself is thoroughly decorticated.

The extent of decortication will be indicated by the needs of the particular case: if the aim is to limit the extent of a proposed or already partially executed thoracoplasty, only the lower lobe will be cleared: combined with an upper lobectomy for persistent cavity or fistula formation the stripping will be equally restricted, though in some instances decortication of the lobe to be excised may be required in the region of the hilum to expose the structures to be isolated unless a pleuro-lobectomy (see later) is to be performed.

Excision of the false membrane from the parietal pleura. Grossly thickened parietal pleura may be an important factor in delaying the restoration of chest wall movements, important in aiding re-expansion and restoring respiratory function; moreover the membrane may be the site of tubercle formations and it is often advantageous to remove it entirely. The disadvantage of this extension of the decortication is that heavy bleeding may be encountered, for the plane of dissection must be through the endothoracic fascia, a tissue rendered abnormally vascular by the severity of the adjacent pleural infection. It is impossible to secure the same plane between the organized "peel" and the parietal pleura as it is on the lung surface and the parietal membrane is included in the stripped tissue.

If the decision is made to remove the parietal thickening it is well to start the whole process of decortication on the parietal surface which is well stripped off the chest wall before the empyema cavity is opened, as the place of separation between this layer and the visceral one is readily found as a thickened ridge where the two meet and the dissection can proceed rapidly on to the lung surface. Occasionally it is possible to remove the whole empyema space unopened.

Before the chest is closed all bleeding must be checked chiefly by the use of hot saline compresses: the space is drained by two catheters, one introduced apically and one posteriorly at the base, and these are connected on return to the ward to a water-sealed drainage system which can be made "negative" by the use of Roberts's suction motor pump (see Fig. 6·7).

Before the chest is closed the anaesthetist re-inflates the lung, which often has a surprisingly healthy pink colour and may be of normal consistency.

The tubes are withdrawn within 48 to 76 hours if radiographs show satisfactory re-expansion which will be the rule in most instances. Active breathing exercises are started the day after operation.

Pleuro-pneumonectomy

The paper read by Sarot to the British Tuberculosis Association at Cambridge in April 1949 greatly influenced the treatment of tuberculous empyema in this country total thoracoplasty and Roberts s operation are far less frequently performed now and the results of pleuro pneumonectomy have exceeded expectations Especially valuable is the radical operation of pleuro-pneumonectomy for pleural empyema associated with active pulmonary disease with or without broncho pleural fistula and for those patients with persistent chest wall sinuses that have not closed even after the most radical of thoracoplasties Pleuro pneumonectomy carries a much lower mortality rate than total thoracoplasty especially for mild infected pyo-pneumothoraces It produces less deformity and is far more effective in the case of chest wall fistula

Persistent chest wall sinuses are the result of a chronically and recurrently infected pleural cavity which in its turn often receives infection from a grossly diseased fistulous lung Even without the addition of pleurectomy pneumonectomy will usually give far better results in this group of cases than will thoracoplasty If the signs of amyloidosis are present the chances of cure will be far greater with lung resection than with thoracoplasty A grave disadvantage of thoracoplasty is that the good effects will not be apparent until the collapse has been achieved by several staged operations and during this precarious period of improvement the other side is under constant risk of infection if a broncho-pleural fistula is present This is not so with pleuro-pneumonectomy for the immediate removal of the major focus diminishes this risk at the end of one operation

There can be no doubt that pleuro pneumonectomy by the extrapleural route of Sarot represents a major surgical advance in the treatment of tuberculous pyo pneumothorax

The operation of pleuro-pneumonectomy A wide exposure is obtained by the sub periosteal resection of the sixth rib the pleural cavity is not opened but the dissection is carried at once into the extrapleural plane the grossly thickened pleura strips readily in the layers of endothoracic fascia but the blood loss is always greater than in the operation of extrapleural pneumothorax When a sufficient space has been created the chest exposure is greatly improved by the use of a powerful rib spreader When the apex of the pleura has been freed with special care being taken not to damage the subclavian artery or vein the dissection proceeds easily in the soft areolar tissue of the mediastinum and as Sarot has pointed out tuberculous involvement of this region is not severe The bronchus *pulmonary* arteries and veins are isolated secured and divided in the extrapleural plane and they are dealt with individually as described on page 280 The pleural membrane with the enclosed lung is then freed from the whole thoracic wall The most difficult area is over the diaphragm where the parietal pleura is densely fused with the muscle and it is frequently impossible to carry out this part of the excision without opening into the empyema space

Bleeding throughout the operation is considerable and adequate transfusion is essential

TUBERCULOSIS OF THE CHEST WALL

Cold abscesses or sinuses developing in the chest wall should not be ascribed to tuber culous osteitis or chondritis ribs and cartilages are often involved in the process but the cause in most instances lies in an underlying caseating lymph gland or represents an extension from a pleural focus or occasionally from a *paravertebral abscess* secondary to tuberculous disease of the spine Burke (1950) has presented interesting evidence that tuberculous disease of the thoracic spine may in fact represent a local extension of disease starting in a

tuberculous pleuritis True haematogenous spread to a rib is very rare If the true pathology of the disease is understood, ill-advised attempts at cure by excising local segments of ribs will be avoided and the development of persistent sinuses avoided

The condition is declining in incidence. most of the patients are middle-aged or elderly, though examples are met with in childhood and early adult life A localized painless swelling develops with the characteristic signs of fluctuation The swelling may appear at a considerable distance from the focus of origin; a cold abscess pointing anteriorly or anterolaterally may have reached that site by tracking there from a posterior intercostal or mediastinal gland or a tuberculous osteitis of a thoracic vertebra A spread from involved anterior intercostal glands may, however, cause an abscess localized above them or spread up or down the posterior wall of the sternum to present in the supra-sternal notch or near the ziphisternum By local extension of the disease the neighbouring ribs or cartilages become involved This extension is more serious when cartilage is concerned and extensive chondritis is a troublesome complication In the natural course of the disease the abscesses may rupture and become persistent sinuses

Treatment of the cold abscess of the chest wall should be as conservative as possible bed rest has been much neglected as a treatment because the patient's general condition is good and they are reluctant to undergo a full sanatorium regime Aspiration of the abscess followed by the local and general use of streptomycin is valuable

If surgery is employed for the removal of necrosed ribs or cartilage, the exposure and extent of the operation must be adequate and the tracks of the abscess must be followed thoroughly so that a caseating gland if present can be removed it is obvious that care must be taken to keep outside the pleura After a thorough excision the wound is closed without drainage

If sinuses are present before the operation, lipiodol could be instilled so that the outline of the tracks may be delineated

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PART IV

CHAPTER 12

NEOPLASMS OF THE LUNG AND TRACHEA

MALIGNANT TUMOURS OF THE LUNG

Primary bronchial carcinoma is clearly the commonest tumour encountered but idary metastatic neoplasms are not infrequent and must be remembered when peri ally placed masses or diffuse infiltrations are under consideration Benign tumours are common (about 4½ per cent of all lung tumours) but more are detected annually as the t of the extended use of radiography and bronchoscopy of this group bronchial enoma is the most important Whatever its true pathology it can be separated cally from bronchial carcinoma by differences of age sex incidence and natural history hich the most important feature is the prolonged survival of many of its sufferers or without treatment

astatic lung neoplasms

Although sarcoma especially of bone is usually fatal because of lung secondaries which o haemoptysis and give rise to typical circular shadows often multiple on the radio- h (Fig 12 1) it is in carcinoma that most lung metastases have their origin and the iary seat of growth may be one of many organs particularly the breast kidney testis y and uterus In all peripherally sited circular tumours a thorough examination of whole body is essential to exclude a primary growth elsewhere

Metastatic involvement of the lung may be in the nature of a diffuse infiltration enting clinically as an intractable pulmonary fibrosis causing an obstinate hard dry gh and dyspnoea the X ray changes are often equivocal It is important to remember such infiltration may develop many years after a successful mastectomy for cancer he breast

Many records now exist in which solitary secondary tumours have been removed by ctomy or pneumonectomy and some long survivals have been noted when the primary vth has been removed also * but usually the metastases are multiple and clearly the test care must be exercised so that unnecessary suffering is not caused by futile attempts palliative surgery If the metastasis is solitary and is causing symptoms such as moptysis eradication is indicated.

Mrs P aged 40 underwent successful hysterectomy for sarcoma of the uterus ten months ere repeated and considerable haemoptysis commenced Radiographs of the chest showed rge ovoid tumour situated in the apical segment of the right lower lobe As the haemoptysis distressing and causing an incapacitating anaemia there being no demonstrable metastases where a right lower lobectomy was done She remained well for nearly a year when metastases eared in the left lung Considered as a palliative procedure the operation was justified as returned to full household duties for a year

* Tudor Edwards (1946) described a patient who was well 18 years after a partial lobectomy done a deposit secondary to a sarcoma of the fibula Seila Clagett and McDonald (1950) have reviewed resections including 10 from the Mayo Clinic: the results were encouraging

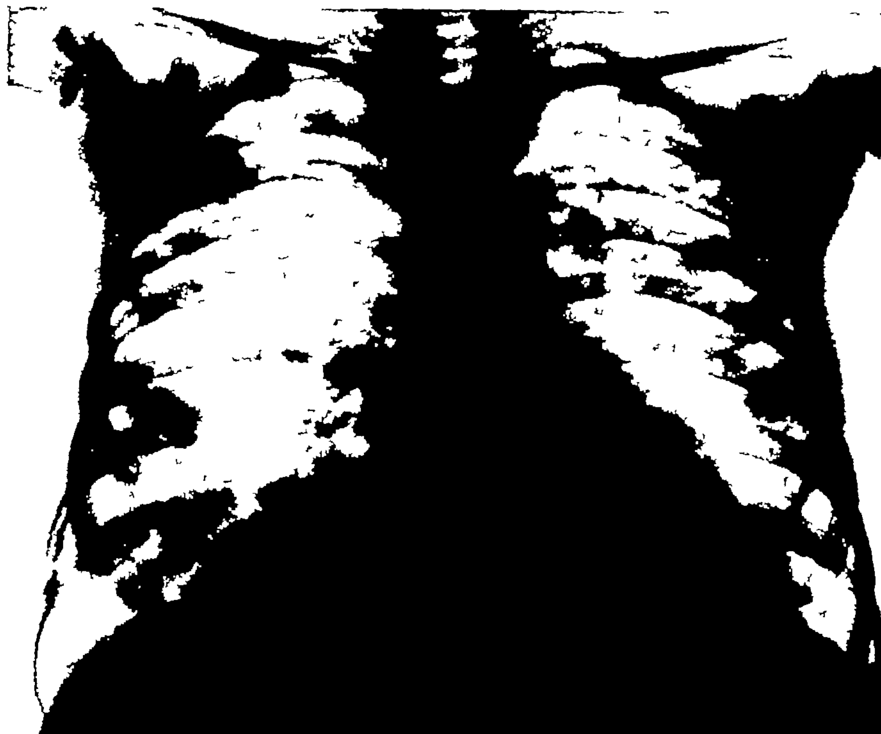


FIG 12 1 —Lung metastases secondary to an osteogenic sarcoma of the thigh

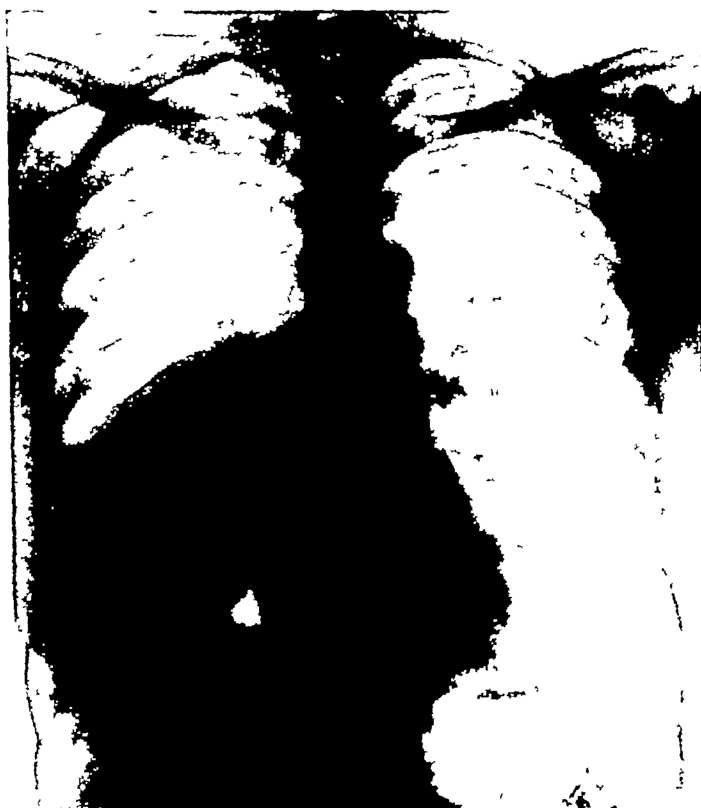


FIG. 12 2



FIG 12 3

FIG 12 2 Radiograph of metastatic lung tumour secondary to uterine sarcoma
The lung metastasis was removed by lower lobectomy

FIG. 12 3 —Circular metastatic tumour in left lower lobe
Right pneumonectomy a year before for carcinoma of right main bronchus

Metastasis of cancer from one lung to the other is unusual though involvement of the lymph nodes at the hilum is common The metastasis in the left lower lobe illustrated in Fig 12 3 is unusual and developed in a man of 60 a year after right pneumonectomy for carcinoma of the main stem bronchus Occasionally both lungs are permeated by carcinoma spreading along lymphatic channels often from a small growth in one side, such lesions may be mistakenly regarded as fibrosis or chronic pulmonary tuberculosis

Primary bronchial carcinoma

Lung cancer is probably the commonest malignant tumour to affect males There is evidence that the incidence has shown a steady rise in the last 25 years this rise is not only attributable to better diagnosis following the increased use of radiology and bronchoscopy but seems to be genuine

In the United States the death rate from carcinoma of the lung in 1920 was 1 1 but had risen in 1936 to 3 6 per hundred thousand (Ochsner 1941) In 1944 carcinoma of the lung was exceeded only by that of the stomach intestines and breast as a cause of death in malignant disease (Vital Statistics of the United States 1944 Washington 1946)

Increased incidence in Great Britain

Paxon (1940) instanced the seriousness of the problem of bronchial carcinoma by the following table of death rates in England and Wales to a million living males

	1935	1940	1945	Increased percentage during 10 years
Stomach	349	409	465	33
Rectum	164	194	238	45
Lung	131	222	370	180

Stocks (1947) believes there is a true increased incidence in the last 30 years and that this is not due to better diagnostic facilities though obviously more patients are accurately diagnosed now He indicates that deaths from lung cancer have not only increased in absolute figures but in proportion to cancer of other sites

(A) *Standardized death rate* (from lung cancer)

Males from 1 1 (1910) to 10 6 (1938)
Females from 0 7 (1910) to 2 5 (1938)

(B) *Percentage mortality due to lung cancer to that due to all sites of cancer*

Males from 1 5 per cent (1916) to 7 9 per cent (1935)
Females from 0·8 per cent (1916) to 2 2 per cent (1935)

Even if all the old faulty diagnoses of sarcoma of the mediastinum of lymphosarcoma and Hodgkins disease were accepted as bronchial carcinoma from hospital and autopsy records its incidence 25 years ago was relatively small The increasing frequency of the disease the hopelessness of the prognosis without adequate surgery and the absence of a clear-cut symptomatology of this disease makes its study of great importance

Since 1938 modern diagnostic facilities have improved greatly and by that date the profession was alert to the need for regarding cancer of the lung as a common condition From 1938 to 1947 the crude mortality rate per million living has doubled from 113 to 228 (Stocks)

Even if there has been no increase in incidence the problem is a considerable one Figures from a University centre may be fallacious on the grounds of special selection but

of patients presenting themselves at the Queen Elizabeth and General Hospitals, Birmingham, in a five-year period, the following table indicates the size of the problem.

TABLE VIII

(From figures prepared by Miss Levi of the Cancer Follow-up Dept)

Year	Number of Cases Registered			
	Breast	Stomach	Colon and Rectum	Bronchus and Lung
1946	428	162	131	150
1947	460	166	135	165
1948	612	158	123	191
1949	486	149	116	201
1950	597	157	285	294
1951	741	316	555	517

These patients were not all in-patients in the University Hospital they represent cases notified to the Cancer Follow-up Department Most of them have been through the wards

In the United Birmingham Hospital cancer of the lung is the commonest malignant tumour seen in the male in the last five-year period In England and Wales about 5,000 persons die annually from the disease

Etiology. The rapid increase in the incidence of bronchial carcinoma has led to enquiry into any specifically "modern" irritant tobacco smoking, petrol fumes, dusts, especially bituminous road surfaces and industrial dusts, have all been suggested as the acusative irritants, but the evidence is too complicated to discuss in a surgical work, at the moment of writing the blame attached to tobacco smoking seems significant Doll and Bradford Hill (1950), after a thorough statistical survey, say that "smoking is an important factor in the production of carcinoma of the lung", and the evidence presented in their article is powerful The contrast provided by figures from Iceland where smoking is not common is striking, for Dungal (1950) pointed out that in the records of 1,939 autopsies performed in Iceland between 1932 and 1948 there were only 12 examples of bronchial cancer out of a total of 417 malignant growths, this is a small proportion compared with figures from other Western countries where smoking has been common since 1914

Although cancer of the lung may develop in the second decade of life it is at present most commonly seen between the ages of 40 and 70 The preponderance of males (6-1) is striking, but the etiological sex difference is as yet unexplained

Occupational hazards In the mines of Schneeberg, lung cancer is common and over half the miners there die of the disease An inhaled, carcinogenic irritant can be assumed to be an operative cause The dust in these mines contains a great variety of potential irritants such as arsenic, cobalt, silica and radio-active substances such as uranium

Irritating substances produced in the chromate industries have been under close observation Machle and Gregorius (1948) found that the mortality of lung cancer in chromate workers over 50 years of age was 40 times that of workers in comparable industrial groups They pointed out that an average of 14 5 years' exposure to the industrial hazard was necessary before carcinoma developed and this agrees with the modern view that carcinogenic dangers may be of slow evolution as in carcinoma of the cervix in women

Environmental factors The larger the city, the higher the death rates from lung cancer Clearly this might be attributable to the better diagnostic facilities and the availability of autopsy and operation room records in the larger centres But such an argument is faulty when comparing the death rates in a residential town like Bournemouth with those of an industrial Huddersfield, the death rate figures in such comparison are greatly loaded against the industrial region Stocks, in explaining these differences, says

either smokiness of atmosphere is an important factor in itself in producing lung cancer or sunshine is an important factor in preventing its incidence His evidence as summarized by Taylor and Waterhouse (1950) is as follows, there is a marked fall in death rate in relation to the hours of sunshine recorded. When 20 large county boroughs were divided into three groups by their mean annual sunshine hours the lung cancer mortality ratios (taking all county boroughs as 100) were as follows

	Hours Sunshine	Cancer Mortality
Group I	Under 1 150	152
Group II	1 150–1 400	100
Group III	Over 1 400	58

When these same 20 boroughs were divided into two groups coastal and inland the average ratios (to all county boroughs—100) were

Sea	66
Inland	138

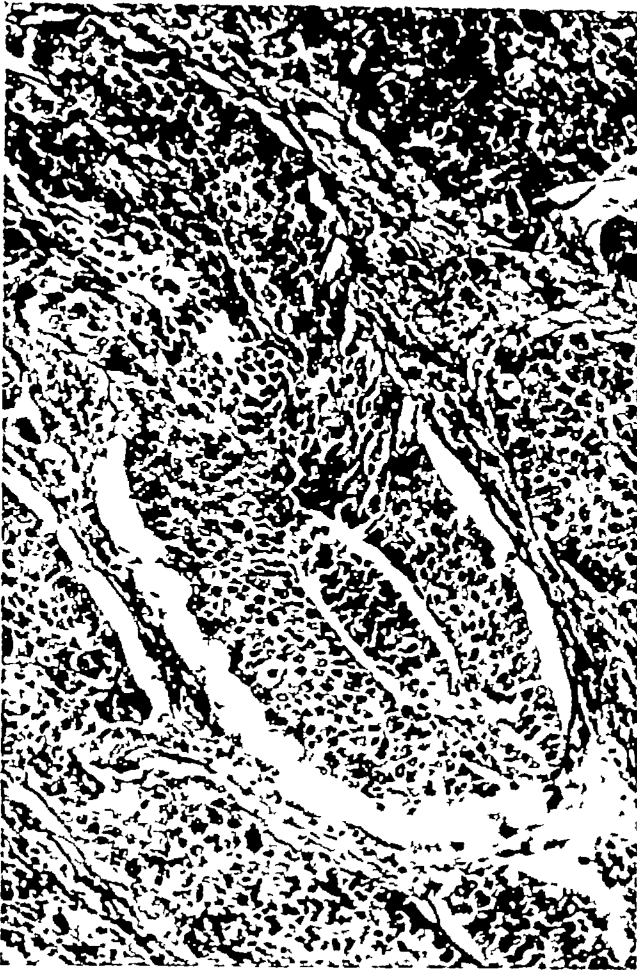
There seems little doubt that lung cancer is commoner in the large industrial towns than in the coastal towns that are not industrial nor could anyone knowing the high standard of doctoring in large seaside towns believe that patients there are less well investigated But coastal position is by no means the only factor for Liverpool has a high incidence of lung cancer

Pathology All lung cancers are probably bronchiogenic and their origin from the alveoli is considered to be unlikely The tumours may be squamous in type or columnar celled though one tumour may show cells of both types Many tumours previously dubbed as 'mediastinal sarcoma' or 'pleural endothelioma' are now known to be bronchiogenic carcinoma

Occasionally reports appear on the condition of 'pulmonary adenomatosis' in humans and this has been compared with the condition known as Jaagsiekte which occurs notably in sheep and dogs and may be infectious in origin In the human there is undoubtedly a malignant diffuse growth in which the macroscopical appearances are those of a lobar pneumonia on histological examination the alveoli appear to be filled or lined with columnar mucous secreting cells and this has led to the suggestion that the state is really one of alveolar-celled carcinoma most pathologists however believe that these cells in the alveoli represent down-growths of malignant cells whose true origin is in the epithelium of the bronchioles The condition has been discussed by Dacie and Hoyle (1942) and Paul and Ritchie (1946) A study of the reported cases does little to support the possibility that malignant disease can develop from lung alveoli

Another cause of confusion is the description of malignant tumours as pleural endothelioma in this condition the lung and pleural membrane is enclosed in a sheath of malignant cells Careful histological study of these cells indicates that they are bronchial in origin and the term is in increasing disfavour though true instances undoubtedly exist

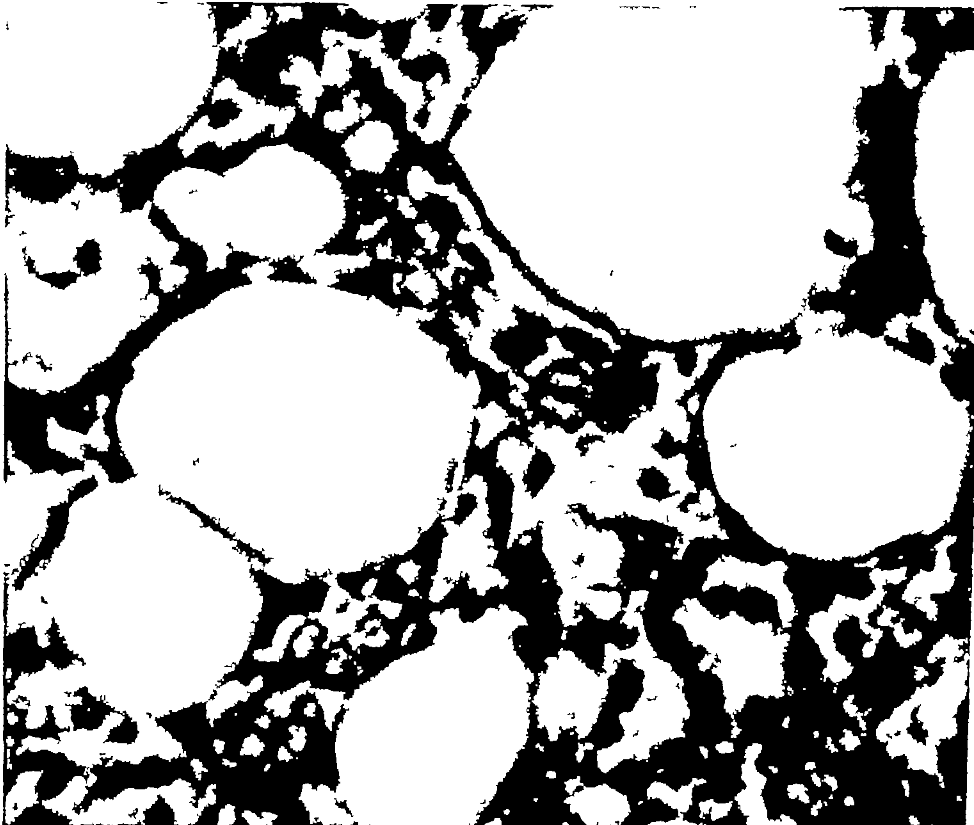
Nomenclature The confused naming of different types of lung cancer depends on the frequent presence in any one tumour of different types of cell which themselves may have undergone varying degenerative or metaplastic processes a squamous carcinoma may have areas of undifferentiated cells of an oat-celled or mucoid type Nevertheless an attempted classification is useful if it is remembered that many tumours cannot be segregated into water tight compartments The commonly accepted trio are (I) squamous-celled carcinoma (epidermoid carcinoma) Fig 12 4 (*a*) (II) undifferentiated carcinoma Fig 12 4 (*b*) and (III) adeno-carcinoma Fig 12 4 (*c*)



(a)



(b)



(c)

FIG. 12.1

(a) Squamous cell carcinoma (× 120)
(b) Oat celled carcinoma of bronchus (× 38) (Prof. J. W. Orr.)
Photograph by Dr. J. G. Jackson
(c) Adeno-carcinoma of bronchus with mucoid degeneration (× 500) (Prof. J. W. Orr.)
Photograph by Dr. J. G. Jackson

The undifferentiated anaplastic carcinoma accounts perhaps for 25–30 per cent the well differentiated and less malignant squamous growth is more common (perhaps 60–70 per cent) with the glandular adeno carcinoma involving about 5 per cent The commonly described oat-celled carcinoma (Fig 12 4 (*b*)) (the old mediastinal sarcoma ') may be a tumour with squamous celled or glandular areas it is an anaplastic tumour with a bad prognosis as mediastinal involvement is early In any large series many patients between 25 and 40 years will be found in this group From the surgical point of view it is well to remember that a portion of tumour removed by biopsy through the bronchoscope may be unrepresentative and thus it is unwise to base prognosis on such sections

The account given above may have the defect of over-simplification and is based largely on the histological examination of pneumonectomy specimens This tends to lower the incidence of oat-celled carcinoma as this tumour often provides a high quota of inoperable patients. Bryson and Spencer (1950) in an analysis of 866 fatal cases of bronchial carcinoma classified the tumours under five headings as follows

Type of Growth	Number of Cases	Percentage
Oat-celled	312	36
Polygonal celled	348	40
Squamoid	97	11 2
Squamous-celled	60	6 9
Adeno-carcinoma	42	4 9
Unclassified	7	0 8
	866	

These authors were however rigid in their selection of cases deemed suitable for classification as squamous tumours and excluded all from that group unless the microscope showed prickle cells or keratin they agree with other writers that bronchial carcinoma is notable for the extreme pleo morphism of its histological structure

The tumours may be peripheral in the main bronchus (75 per cent of lung cancers are in areas of the bronchial tree visible at bronchoscopy and are suitable for biopsy) or in a small bronchus When located close to the mediastinum that area may be rapidly invaded especially by oat celled carcinoma in the younger patient

Over three-quarters of the tumours develop in the main stem bronchus with the right lung more frequently affected than the left Simons (1937) in a series of 2 177 found the right lung was affected in 1 147 but in the same group the left upper lobe was more often affected than the right upper one

The best prognosis after pneumonectomy for cancer of the lung is in the squamous celled group Quite exceptionally the cancer may be diffuse involving both lungs (pulmonary carcinomatosis diffuse lymphatic carcinoma malignant adenomatosis) and radiologically this type may be confused with miliary tuberculosis diffuse bilateral pulmonary diseases or pneumonia

It is not possible to foretell the likely spread of bronchial carcinoma either by radio logical or histological methods huge tumours may be slow in producing local or distant metastases while a small almost undetectable growth may be the origin of a shower of metastases especially to the brain a fact well known to neuro-surgeons

The Pancoast or superior sulcus tumour This tumour, about which much has been written is a bronchial carcinoma which develops in the apex of the lung (Fig 12 5) because of its site it invades the neighbouring structures such as the adjacent ribs the brachial

plexus and the sympathetic nervous chain, causing severe local and brachial plexus pain associated with Horner's syndrome



FIG 12 5—Radiograph of superior sulcus tumour causing opacity at right apex The patient, a man of 48, complained of severe brachial neuritis, he had a Horner s syndrome

Local effects and complications of the tumour. The tumour may spread along the peri-bronchial plane of the bronchus of origin or grow into the lumen which becomes obstructed The peri-bronchial spread is of great importance, because on radiological examination the effects of this may be represented by atelectasis of areas of the lung, the result of extrabronchial pressure producing a complete stenosis At bronchoscopy, although the stenosis will be detected readily, the actual tumour may not be visible. In peripherally placed growths, spread into the loose parenchyma of the lung may be rapid with central necrosis producing a cavity which may look deceptively like a simple lung abscess on the radiograph (Fig 12 8), or into the adjacent parietal pleura or overlying ribs which may become decalcified and then eroded The squamous type of tumour when sited in the periphery of the lung has a special tendency to cavitate The radiological appearances may thus be confused with those of lung abscess or a liquefying tuberculoma

When the tumour blocks a main lobar or segmental bronchus the effects are those of bronchial occlusion Occasionally growth may spread across the carina to block the other side; the airless lung collapses, and secretions in it stagnate from loss of ciliary action and from blockage Infection is common in this area of atelectasis and this may proceed to lung abscess formation—a strong reason for employing bronchoscopy in cases of lung abscess If the obstruction is prolonged sufficiently the bronchial walls in the collapsed area dilate and bronchiectasis develops A bloodstained pleural effusion may follow and the continuing suppuration in the lobe or segment distal to the blocking growth may initiate an empyema, often insidious, atypical and unsuspected

More distant effects As elsewhere the tumour may spread by direct invasion by lymphatic spread and by blood borne metastasis The spread into veins is far commoner than to arteries and the growth may actually project from a pulmonary vein into the left auricle from such a projection a large tumour embolus may become detached and cause sudden death Direct spread to the mediastinum and pleura is common and the pericardium is occasionally invaded Typical symptoms may follow compression or infiltration of nerves such as the recurrent laryngeal the phrenic nerve or the brachial plexus Occlusion of the superior vena cava will obstruct the venous return from the head neck arm and thoracic wall involvement of the oesophagus produces dysphagia and finally broncho-oesophageal fistula The invasion of the pericardium and pleura causes effusions Lymphatic extensions produce enlargement of the thoracic glands especially in the mediastinum more with cancer of the right lung than of the left as there is a greater aggregation of lymph glands in the right superior mediastinum than on the left side massive glandular involvement may cause a larger radiological shadow than that of the primary tumour The lymphatic spread may be extrathoracic to the glands of the supra-clavicular triangles or the abdomen and much less commonly to the axilla Occasionally a chylous pleural effusion develops as a result of blockage of the lymphatic duct Osteoarthropathy and a rheumatoid type of arthritis may be seen in these patients and may disappear dramatically after pneumonectomy In a few patients a great increase of blood flow to the lower limbs (the explanation of which remains obscure) may be so significant that the patient s chief complaint is of hot feet (N R Barrett first drew my attention to this oddity)

Blood-borne metastases In advanced fatal cases these are seen in three-quarters of the patients (Willis 1948) The common sites are the central nervous system the adrenals the skeleton the liver and the skin These metastases are usually multiple but occasionally a solitary metastasis justifies its operative removal especially when cerebral The peri pherally placed tumours may produce metastases more rapidly than those developing in a main stem bronchus because the lung parenchyma has a rich network of thin walled vessels readily invaded by tumour cells

Rate of growth and prognosis in untreated cancer of the lung The course of lung cancer is often unpredictable The expectation of life in Brian Taylor s series of 1 592 lung carcinomata not treated by surgery was on an average 4 months It is strange but important to note that patients with a long history may have the longest survival period because of the slow rate of growth. This is important surgically because many of these patients with a long history of haemoptysis and cough are operable at thoracotomy Probably many tumours exist long before symptoms occur and as survival rates are based usually on the expectation of life from the date of symptom development the statistics on the subject are not reliable evidence of the real length of the tumour s history

Clinical features and diagnosis Taylor has made a study of 1 592 proved cancers of the lung seen at the Queen Elizabeth and General Hospitals Birmingham and through the efforts of Miss Levi has traced every patient with the exception of one These patients were seen between 1936 and 1948 Startling features of his investigation are that symptoms were present on average for 5 5 months before the correct diagnosis was made In the patients not treated by pneumonectomy the average survival rate after diagnosis was 4 months although three patients survived for three years without surgical treatment To disarm criticism of the medical service in the area it is permissible to quote from Taylor s paper that Overholt and Schmidt (1949) found in their area that for 1932–42 symptoms were present on an average for 11½ months before being accurately diagnosed and that in 1947–48 the delay was represented by a figure of 10 months The delay in diagnosis is due

to a lack of classical pattern in the symptoms and the failure to use radiology and bronchoscopy earlier In the absence of early radiological detection (yearly the number diagnosed by mass miniature radiography increases) diagnosis is impossible probably in 10 per cent of patients in an early stage treatable by pneumonectomy, for Taylor found that in this

TABLE IX

ANALYSIS OF FIRST SYMPTOMS BY TYPE (WHEREVER STATED) AT BIRMINGHAM UNITED HOSPITALS

Symptoms	Number	Percentage
Cough	434	28·7
Pain	332	21 9
Dyspnoea	194	12 8
Haemoptysis	116	7 7
Pneumonia	40	2 6
Pleurisy	31	2 0
Bronchitis	43	2 8
Sickness and indigestion	31	2 0
Swelling (neck and throat)	35	2 3
Alteration of voice	28	1 8
Loss of weight	18	1 2
Superficial metastases	8	0 5
Dysphagia	10	0 7
Malaise	37	2 4
Exhaustion	9	0 6
Night sweats	6	0 4
Tightness (chest and throat)	11	0 7
Neurological	93	6 1
Other	38	2 5

(After Taylor and Waterhouse, 1950).

percentage the first presenting symptoms indicated inoperability in a group of 604 consecutive patients, 11 4 per cent first consulted their doctor for symptoms that were not pulmonary

	per cent
Neurological	6 1
Voice changes (due to recurrent laryngeal nerve paralysis)	1 8
Swelling of the neck (vena caval obstruction)	2 3
Superficial secondary metastases	0 5
Dysphagia	0 7
Total	11 4

Significant symptoms such as cough, haemoptysis or dyspnoea indicate the need for full enquiry, but even when added together scarcely exceed 50 per cent of the presenting symptoms in what can be a silent process

Symptoms. The symptoms of carcinoma of the lung are notably unreliable and without classical pattern but are of greater diagnostic help than clinical physical signs which are rarely detectable in early, operable cases Fortunately, radiology is able to detect all but few and by far the best way to achieve early diagnosis is to suspect the diagnosis, largely on history, and then to follow this by radiography Early diagnosis can be achieved by publicizing the vague early symptoms, by stressing the value of radiology and bronchoscopy, and by realizing the extreme limitations of the stethoscope Rienhoff (1947) found radiological changes in all of 327 cases of operable bronchial carcinoma but the diagnosis can

still be made in the rare instance of a normal radiograph if bronchoscopy and wet film cytology is used

However patternless the symptoms most patients with this disease have lung complaints and in a reported series over 80 per cent have had pulmonary symptoms of which chronic cough with or without haemoptysis is the most common Cough however affects a huge group of patients such as the bronchitic and the smoking coughers in this age group Perhaps the only clue that will suggest the advisability of a radiograph is an alteration in the type character or frequency of the coughing Persistent cough often with pyrexia after a cold may be the first clinical indication of the neoplasm and the diagnosis may masquerade under those most dangerous of chest diagnoses— unresolved atypical or recurrent pneumonia

Dyspnoea (not always easy to explain because it may be an important feature in small peripheral tumours) and pain are less common in the early stages though obvious in the late often untreatable disease Haemoptysis which usually presents itself as a streaking of the sputum is often lacking though a symptom of cardinal importance indicating without fail that radiology is essential. The older teaching of the significance of prune juice sputum is valueless so rarely is it seen

Loss of weight anorexia severe chest wall pain or brachial neuritis and widespread symptoms due to metastases are signs of prognostic value but often too late for useful early diagnosis

In elderly patients especially an empyema may arise be diagnosed and treated without an underlying lung cancer being appreciated Wheezing often recognized in the early stages as unilateral by the patient is an unusual but important symptom

Symptoms due to complicating infection the result of atelectasis These after cough, are the most important group If a main stem bronchus or a lobar branch is obstructed by tumour the resultant infected atelectasis may produce cough dyspnoea and pyrexia with expectoration of grossly purulent sputum which may be blood-stained The patient will be anaemic with a leucocytosis and a wrong diagnosis of abscess or ' pneumonia ' may be made

The onset of such atelectasis may be sudden at the moment when occlusion becomes severe the sudden pyrexia the pleuritic pain that often accompanies the collapse and the systemic effects of toxaemia the result of pent up secretions may well lead to a provisional diagnosis of pneumonia which in itself may respond to chemotherapy for a short period If then the temperature rises the diagnosis of empyema is often considered long before the possibility of an underlying neoplasm In my experience in this group in the middle aged and the elderly carcinoma is far more common than empyema It is unwise to allow a middle aged subject to convalesce from pneumonia without a radiograph being taken If a shadow suggesting a tumour is present on such a radiograph effective diagnostic action can be taken by using the bronchoscope *No diagnosis of unresolved pneumonia pneumonitis or atypical virus pneumonia should be made in the age group of 40 to 80 without full diagnostic investigations (radiology bronchoscopy examination of sputum by wet film method)*

Physical examination The stress placed on radiology bronchoscopy and histological methods of diagnosis does not imply that a full clinical examination is to be over looked the routine methods of examination of the chest are followed by palpation of the lymph nodes of the neck and axilla and of the liver No patient with bronchial carcinoma is completely examined unless the central nervous system is carefully scrutinized for effects produced by possible metastases Indirect laryngoscopy may show paralysis of

the left vocal cord when the recurrent laryngeal nerve on that side is caught in the neoplastic process, indicating its extension to the mediastinum between the upper lobe bronchus and main bronchus Though not necessarily preventing resection of the lung it points to less chance of successful extirpation

Involvement of the phrenic nerve on the side of the mediastinum is shown by a raised diaphragm with paradoxical movement seen on X-ray screening Again, excision is not necessarily precluded but the growth must have extended to the pericardium in such patients

Clubbing of the fingers in lung cancer may be rapid and not infrequently associated with painful pulmonary osteoarthropathy, I have seen five patients whose presenting symptom was severe pain, and swelling in large joints These arthritic symptoms are invariably relieved if pneumonectomy can be performed

Radiology. The appearances will depend upon the site and size of the tumour.

The peripheral tumour. These form 2 to 15 per cent of lung growths in different published series the circular outline may give a false feeling of security, suggesting to the inexperienced that the tumour is an innocent, encapsulated one (Fig 12 6) These tumours, because they lie in a rich blood and lymphatic bed, metastasize earlier than the stem tumours and therefore require early eradication They may be detected by mass radiography when quite symptomless

Differential diagnosis of peripheral tumours This is peculiarly important and difficult because many of the imitators are as symptomless as serious peripheral cancers the latter may be sharply circumscribed though rarely as well defined in their outline as some innocent tumours (extrabronchial adenoma, "hamartoma", chondroma, hydatid cyst see p. 288)



Fig 12 6



Fig 12 7

Fig 12 6—Radiograph of a patient of 58 with an ovoid tumour of the left lower lobe Histological examination after lobectomy revealed squamous carcinoma

Fig 12 7—Carcinoma of right upper lobe simulating a lung abscess The man had cough with haemoptysis for six months Bronchoscopical biopsy showed squamous carcinoma



Fig 12 8.—Atelectasis due to carcinoma of bronchus.

Segment 1 collapse of the lingula, due to bronchial carcinoma. The histology of a bronchoscopic biopsy was that of squamous carcinoma.



(a)



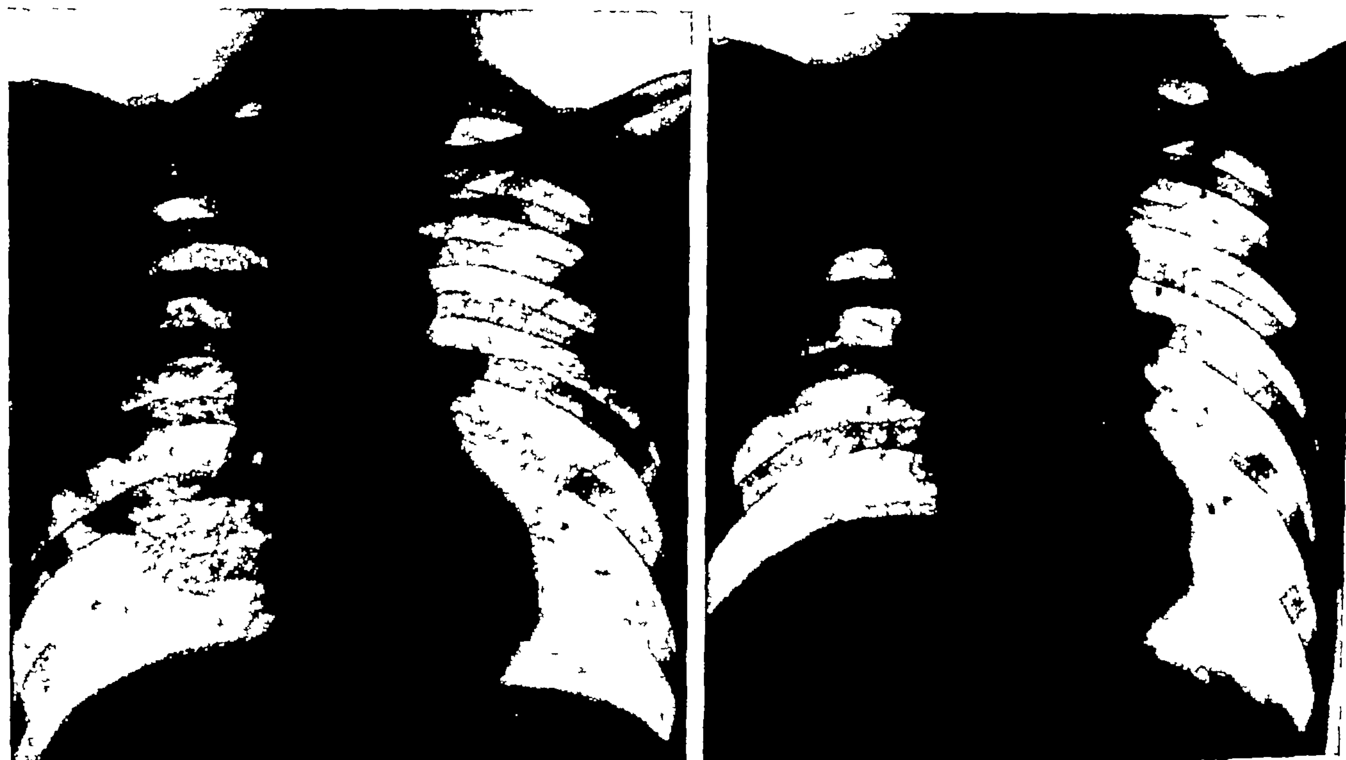
(b)

Fig 12·9

(a) Atelectasis of left lung due to carcinoma of main stem bronchus.
(b) Pneumonectomy specimen showing carcinoma obstructing the main bronchus.

They usually have clearer margins than lung abscess with which they may be confused, the peripheral cancer that has liquefied in the centre usually has a thicker wall than the lung abscess Secondary metastases if multiple are readily differentiated but may be the cause of error if solitary Extrapulmonary tumours such as neurofibroma, dermoid cysts and retro-sternal goitre have their own characteristics (see p 462) Angiocardiography may be of help in the differential diagnosis (see p 344)

Inflammatory masses are the chief cause of diagnostic error A tuberculoma or persistent primary focus may imitate a peripheral cancer and the difficulty in differentiation is one of the reasons given for advising excision of the chronic nodular lesion (see



(a) (b)

Fig 12 10

(a) Radiograph taken of the chest of a man of 48 because of haemoptysis

He was admitted to a sanatorium with the diagnosis of pulmonary tuberculosis of right upper lobe

(b) 8 months later

There is an obvious hilar mass with atelectasis of the right upper lobe and paralysis of the right leaf of the diaphragm which on screening examination moved paradoxically

Chapter 10), but local areas of suppurative pneumonia may be impossible to differentiate, even after the chest has been opened

The danger of ignoring small peripheral masses detected radiologically in the lung is now too well known to require further emphasis

Bronchial stem growths Apart from bronchography or tomography, which may show a bronchial block, these tumours are not usually demonstrated as space-occupying masses, but they cause radiological shadows because of the associated obstruction of a segmental (Fig 12 9), lobar or main stem bronchus (Fig 12 10), when a picture of atelectasis may be demonstrated Before the lobe or segment collapses, anatomical changes may be evident and the appearance at this stage may be mistaken for pulmonary tuberculosis Occasionally obstructive emphysema is seen in the affected lobe, though compensating emphysema is more often apparent in the other lobe following collapse of its fellow Atelectasis, however

limited requires bronchoscopic examination and nothing can be more dangerous than a report advising the taking of another film in three months time

Often the actual tumour mass (Fig 12 10 (*b*)) and its extension to the mediastinal lymph glands can be seen with enlargement or distortion of the mediastinal shadow The presence of a pleural effusion or of rib erosion denotes an advanced stage of growth

The study of oesophagograms Brock has indicated that careful studies of the radiological visualization of the oesophagus may indicate the extent of the extrapulmonary spread of lung cancer and that gross distortion or involvements of it may avoid an unnecessary thoracotomy Before accepting an oesophagogram as presenting evidence that the tumour is inoperable great experience is needed in interpreting the appearances.



Fig 12 11 —Oesophagogram in a patient with inoperable carcinoma of the lung

The mid thoracic oesophagus is obstructed and shows persistent defect on screening A palliative pneumonectomy was performed, and the tumour had invaded the outer layer of the oesophagus.

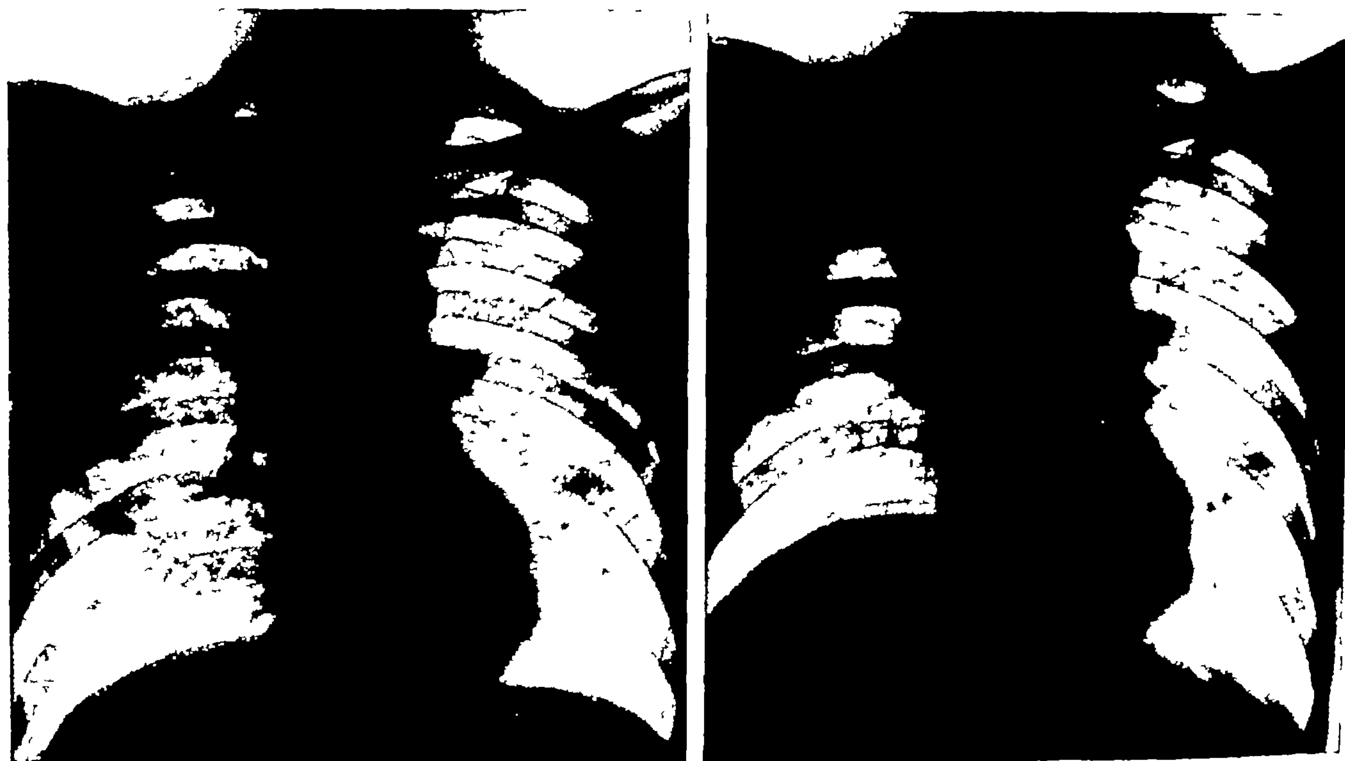
Bronchoscopy Since 75 to 80 per cent of growths can be seen through the bronchoscope this examination is essential when symptoms and radiology have suggested a possible neoplasm The method is safe and simple and can be carried out under local anaesthesia Moreover in most stem growths a biopsy can be taken and histological evidence of the exact type of tumour obtained. Even when the growth itself is not visible distortion, or bronchial occlusion from the extrinsic pressure of a tumour may support a pre-bronchoscopic suspicion of growth

The assessment of operability by the bronchoscope Important signs of inoperability are a paralysed vocal cord or spread of growth to the trachea If the mediastinum is extensively invaded the bronchi are rigid and fixed and the carina may be bulged upwards by tumour invasion of the inferior tracheobronchial glands Exceptionally the growth may have spread over the bifurcation into the opposite bronchus

Cytological examination of the sputum and other histological methods The examination of the sputum by the wet film method so earnestly advocated in this country by Dudgeon (1935) and consistently supported by Barrett has at last been adopted and as high a proved rate of 80 per cent has been achieved by some workers The technique and reading of the film requires great experience and morning specimens of sputum should be carefully collected probably these sputa are more valuable than those obtained by saline washing aspirated from the bronchi during bronchoscopy as the material is more concentrated and many specimens can be obtained The method is of special value in the investigations of tumours that are out of vision of the bronchoscope and often the best cytological studies seem to be possible in these obscurely placed lesions The method is now far beyond the experimental and tentative stage and if used is of the greatest diagnostic value Even in 1943 Cowar could report the presence of cancer cells in the sputum in 64 3 per cent of 93 proved lung growths

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(*a*) (*b*)

Fig 12 10

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Fig 12 11 —Oesophagogram in a patient with inoperable carcinoma of the lung.

The mid-thoracic oesophagus is obstructed and shows persistent defect on screening. A palliative pneumonectomy was performed, and the tumour had invaded the outer layer of the oesophagus

Bronchoscopy Since 75 to 80 per cent of growths can be seen through the bronchoscope this examination is essential when symptoms and radiology have suggested a possible neoplasm The method is safe and simple and can be carried out under local anaesthesia Moreover in most stem growths a biopsy can be taken and histological evidence of the exact type of tumour obtained Even when the growth itself is not visible distortion or bronchial occlusion from the extrinsic pressure of a tumour may support a pre-bronchoscopic suspicion of growth

The assessment of operability by the bronchoscope Important signs of inoperability are a paralysed vocal cord or spread of growth to the trachea If the mediastinum is extensively invaded the bronchi are rigid and fixed and the carina may be bulged upwards by tumour invasion of the inferior tracheobronchial glands Exceptionally the growth may have spread over the bifurcation into the opposite bronchus

Cytological examination of the sputum and other histological methods The examination of the sputum by the wet film method so earnestly advocated in this country by Dudgeon (1935) and consistently supported by Barrett has at last been adopted and as high a proved rate of 80 per cent has been achieved by some workers The technique and reading of the film requires great experience and morning specimens of sputum should be carefully collected probably these sputa are more valuable than those obtained by saline washing aspirated from the bronchi during bronchoscopy as the material is more concen trated and many specimens can be obtained The method is of special value in the investi gations of tumours that are out of vision of the bronchoscope and often the best cytological studies seem to be possible in these obscurely placed lesions The method is now far beyond the experimental and tentative stage and if used is of the greatest diagnostic value Even in 1947 Gowar could report the presence of cancer cells in the sputum in 64 3 per cent of 93 proved lung growths

Direct lung puncture is unwise because of the dangers of bleeding and of producing pneumothorax and pleural infection in a few peripheral tumours with bony involvement the method might be justifiable Biopsy of enlarged lymph nodes in the supra-clavicular fossae and the axilla is of occasional value and may be less upsetting than a bronchoscopy in a patient who will be inoperable if the histological study of such gland biopsies is positive Skin or subcutaneous metastases can also be excised and will show the nature of the primary growth

Exploratory thoracotomy

If the clinical history and the radiological examination support a diagnosis of bronchial carcinoma, exploratory operation will be indicated, even if bronchoscopy and sputum examination have been negative , if appeal was not made to this procedure many peripheral carcinomata would miss resection in the early stages In practice few errors are made but it is often difficult to persuade a patient with a symptomless tumour, perhaps discovered on mass radiological examination, to submit to this procedure It is not always possible even at thoracotomy to be sure of the diagnosis and occasional errors will be made the use of frozen histological sections will not ensure complete accuracy but the lobectomies and pneumonectomies performed on inflammatory lesions are few and often prove to be the most efficient treatment

The operability rate. This unfortunately remains low and varies between 15 per cent and 40 per cent according to the type of material being operated upon The dismal figure of 1 4 per cent reported by the British Empire Cancer Campaign Committee in 1943 is not true today Brock's figures are of value and provide encouraging evidence that earlier diagnoses are being made

CASES OF BRONCHIAL CARCINOMA 1941–48

Total seen	800
Thoracotomy	172
Operable	106

Average operability = 13 25 per cent

Last four years (1945–48) 449 cases, 83 operable = 19 per cent

1945	15 per cent
1946	13 per cent
1947	21 per cent
1948	23 per cent

The highest operability rate is recorded in the series of patients discovered by mass radiography and is in the region of 30 per cent This is significant when the fact that nearly 400 cases diagnosed by this method have been recorded (Paxon, 1949)

Operability rates are not strictly comparable from different clinics in some hospitals palliative pneumonectomy is employed, when the operative findings show that " cure " is impossible because of extensive mediastinal involvement, in the hope that the last few months of life will be more tolerable if haemoptysis or septic effects from a lung grossly infected distal to a tumour are stopped When the criteria for thoracotomy are based on scrupulous pre-operative choice the resection rate is high , in the series of 681 proved cases of lung cancer at the Massachusetts General Hospital, Churchill and others carried out thoracotomy on 294 and performed lobectomy or pneumonectomy in 171, a resection rate of 58 2 per cent But th[illegible]thors themselves are careful to point out that in the period under review 1 130 patient[illegible]itted in whom a clinical diagnosis of cancer was made and

that in 681 this clinical diagnosis was confirmed by actual histology the remainder being excluded from the resection rate survey

In patients referred directly to thoracic surgery in the Queen Elizabeth Hospital Birmingham the resection rate has been 45 per cent in the last four years naturally such a selection raises the rate because the obviously inoperable cases are not referred for treatment In a large series of bronchial carcinoma seen by Taylor on the medical side at the same hospital the resection rate has been 20 per cent

Treatment of bronchial carcinoma

Pneumonectomy or lobectomy The removal of the whole lung together with the mediastinal lymph glands by dissection pneumonectomy is the best treatment when the growth is confined to the lung and has not extended either directly or by metastases to such an extent that this is no longer possible Considered from an anatomical point of view the lymphatic channels of the lung are widely inter-connected with no lobar barriers and lobectomy as an operation is as apparently illogical and ill-conceived as the excision of a cancerous segment of the breast Nevertheless there is a place for lobectomy in this disease and in recent years the number of patients submitted to this less radical procedure has increased The obvious aim at radical surgery must be modified by circumstances chiefly of a physiological nature if total lung resection will produce a respiratory cripple lobectomy is preferable With careful selection Churchill (1950) and others between 1930 and 1950 performed 57 lobectomies as against 114 pneumonectomies and the follow up results did not disclose any notable difference in results these excellent results depended on a selection which allowed lobectomy for strictly localized cancer and the operative procedure included as full a lymph node removal as possible Lobectomy was practised in patients with diminished cardiac or pulmonary reserve and when the exact diagnosis at operation remained uncertain it was used for small peripheral lesions and to provide satisfactory palliation in a patient when resection whether total or lobar could not be regarded as curative

Briefly the indications for lobectomy are

1 In the elderly with poor cardio-respiratory reserve where the growth has not extended clinically beyond the lobe In such patients the slower rate of growth and a lower operative mortality rate often justifies lobectomy

2 In circular peripheral tumours without glandular involvement especially when doubt prevails as to the exact diagnosis (I have been grateful on six occasions that lobectomy was done for such categories in two the lobe contained hydatid cysts in two the peripheral type of ' adenoma that was largely extrabronchial in one the specimen contained a hamartoma and the last was a case of chronic lung abscess The pre-operative diagnosis in all six was bronchial carcinoma)

Pneumonectomy however remains the obvious operation in most patients for only by this method can a radical block dissection be practised the lung glands and mediastinal areolar tissue being resected in one piece The operation can be truly radical if the intra pericardial method of Allison is practised together with a wide resection of pericardial tissue and removal of the mediastinal and tracheo bronchial lymph glands *en bloc*

Is excision a worth while procedure? In all forms of cancer surgery there are inevitably waves of pessimism and optimism In cancer of the lung we cannot pretend that results are outstandingly good but resection provides incomparably better results than no treatment or care by radiotherapy The operative mortality rate is now about 10 to 15 per cent and

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has fallen steadily in recent years with better anaesthesia, better operative technique and advances in post-operative treatment

Taylor and Waterhouse (1950) have shown that in Birmingham the mean duration of disease from the first symptom is 9 9 months when surgery is not employed and that in all the pneumonectomy cases this figure is 18 4 months, rising to 23 3 months if the immediate mortality figures are excluded In a series of 1,147 patients subjected to pneumonectomy by different surgeons in Great Britain, 52 7 per cent had survived one year, 33 3 per cent two years, 23 9 per cent three years, 18 7 per cent four years and 13 7 per cent five years *

These results, though far from happy ones, are a great improvement on the natural survival rate for the disease They should be capable of improvement with earlier diagnosis and earlier surgery

Radiotherapy. The use of radium or radon which was employed previously as a palliative method to relieve the effects of bronchial obstruction has been superseded by deep X-ray therapy which often produces helpful palliation Radiotherapy may be employed as a *radical* or *palliative* procedure For radical therapy the patient must be in hospital in bed, as the course extends over several weeks and may cause considerable distress, often involving the giving of between 4,000 and 5,000 Rontgen units delivered through carefully placed fields of wide distribution the details of therapy cannot be given here

The chief indications for radiotherapy are

(1) in patients with the anaplastic type of undifferentiated growth These are often of " mediastinal type " shown to be inoperable by clinical, radiological, bronchoscopic or operative findings ,
(2) in patients with superior vena caval obstruction ,
(3) in the young age groups (18–30 years) ,
(4) as a post-operative measure when the pneumonectomy has been carried out in the presence of obvious glandular involvements ,
(5) as a palliative measure for severe pain when the condition is inoperable ,
(6) in patients who clinically are on the border-line of operability because of suspected mediastinal invasion, radiotherapy may be used as a pre-operative measure There is a tendency at the moment to apply this combination in an increasing number of patients

Some surgeons would widen these indications by advising radiotherapy for most patients with undifferentiated anaplastic tumours as revealed by bronchial biopsy and by using it post-operatively as a routine after resection

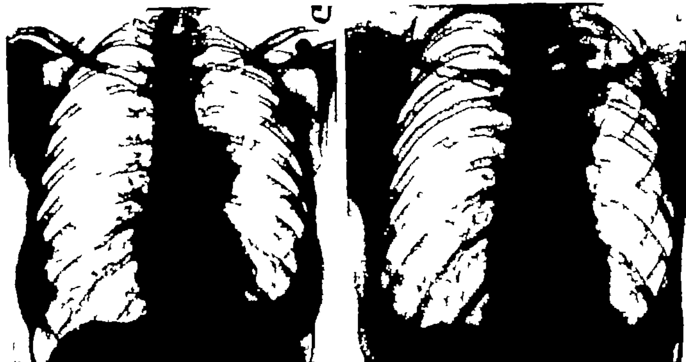
Radiotherapy should not usually be employed in old feeble patients or when severe cachexia is present, for the treatment often aggravates the asthenia and dyspnoea it is usually inadvisable when pleural fluid or gross sepsis such as empyema or lung abscess is present Sometimes, however, a palliative course of deep X-ray therapy may unblock a main stem bronchus obstruction and lead to dramatic relief of sepsis by allowing the patient to expectorate the pent-up secretions

I have on many occasions been grateful to the radiotherapist for the relief of symptoms that has followed in quite inoperable patients and I certainly do not subscribe to the view that radiotherapy is valueless

Operative procedures in pneumonectomy for bronchial carcinoma. The aim is to remove the whole lung with its associated lymphatic field as widely as possible There

* More recent follow-up indicates that in patients without glandular involvement the five year follow-up shows 25–35 per cent survival figures

is considerable support today for the wider use of Allison's intrapericardial ligation of large vessels associated with removal of much of the pericardium and of the loose tissue of the mediastinum from high up in the thorax down to the diaphragm together with a block dissection of the lymphatic glands around the main bronchus stem in the tracheobronchial angle and around the pulmonary artery superior and inferior pulmonary veins This operation originally designed to extend the scope of lung excision to include cases of extra pulmonary spread to the pericardium can well be employed as the routine operation of total pneumonectomy and it fulfils the precepts of *radical cancer surgery* It has not



(a) (b)

Fig 12 12

(a) Radiograph of a woman of 32 with mass adjacent to mediastinum.
At thoracotomy this tumour was inoperable with extensive invasion of the pericardium. Biopsy showed an anaplastic oat-celled carcinoma. (Radiotherapy by Dr J Bromley)

(b) Radiograph of the same patient 3 years later
The left upper lobe is atelectatic but a large amount of the ovoid mediastinal mass has disappeared. There were no symptoms and the patient [illegible] at full work.

however displaced entirely the use of extrapericardial dissection pneumonectomy for cancer of the lung when the growth is early without mediastinal or glandular involvement Even when the glands in the neighbourhood are extensively invaded palliative pneumonectomy is often indicated to relieve persistent haemoptysis expectoration of infected sputum and pyrexia the result of lung abscess and atelectasis or bronchiectasis distal to the growth itself Involvement of the parietal pleura and the ribs adjacent to the tumour does not necessarily preclude a satisfactory excision for the dissection may be carried into the extrafascial and the extracostal plane and include segments of the whole chest wall

The operations to be considered therefore are

A Routine dissection pneumonectomy
B Radical intrapericardial pneumonectomy
C Extrapleural pneumonectomy
D Lobectomy

Anaesthesia If the patient has much sputum the bronchus can be occluded by means of the Thompson blocker (Fig 4·2) After premedication, followed by pentothal, supplemented by curare a bronchoscope is passed and any pus seen in either bronchus is sucked

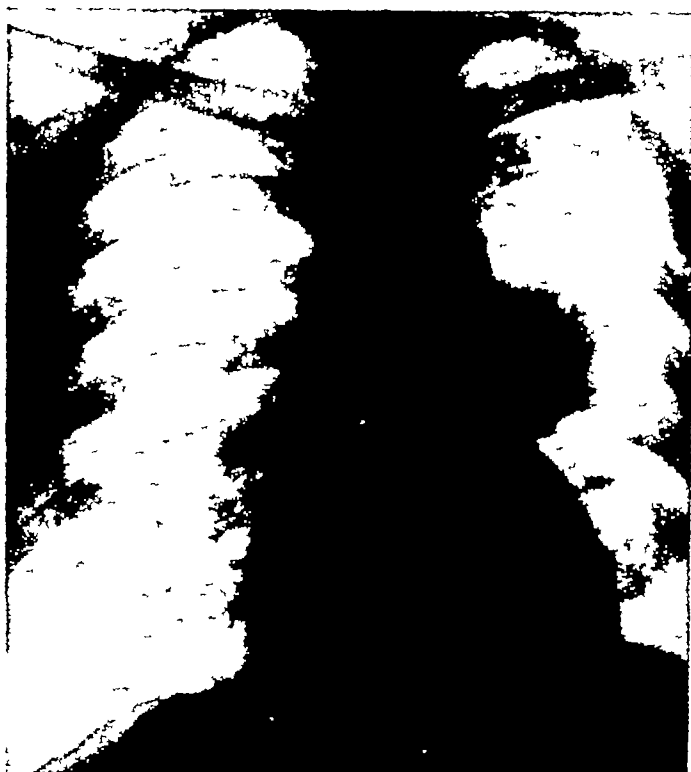


FIG 12 13 —Mass at hilum of left lung · the left leaf of the diaphragm is raised and moved paradoxically on screening, indicating involvement of left phrenic nerve

At thoracotomy this tumour was operable by the intrapericardial method a large portion of pericardium together with the phrenic nerve being excised.



FIG 12 14 —Pneumonectomy specimen of carcinoma of lung

The tumour had involved overlying ribs which were removed together with the lung the segment of removed chest wall is to the right

out . the blocker is passed below the carina into the main stem bronchus of the affected side and the balloon on its tip is inflated The bronchoscope is withdrawn leaving the blocker in place , a large-bore intratracheal tube (Magill) is then passed into the trachea

and anaesthesia maintained by pentothal curare and oxygen or by the method preferred by the particular team Controlled respiration undoubtedly provides a quiet operative field and prevents the build up of CO_2 tension in the blood if the carbon dioxide absorption is efficient

Position on the table This is by no means standardized there are at least three recognized positions

(1) The supine position this allows the surgeon to enter the thorax through an anteriorly placed incision (Rienhoff) It is not widely used in this country because the access to the lung hilum is inferior to that provided by the posterolateral thoracotomy position The incision had the advantage of keeping the mediastinum more central than in the lateral approach in the early days of thoracic anaesthesia but this can be maintained by modern controlled respiration

(2) The normal classical posterolateral thoracotomy incision

(3) The head-down position for a posterior approach (the Overholt or Holmes Sellors position) This position enables the secretions from the bronchi to flow out by gravity through a large intratracheal tube which has a special trap to collect them It also prevents the falling away of the mediastinum towards the lower non-operated side that is sometimes seen in the lateral thoracotomy

The operation of pneumonectomy through a posterolateral thoracotomy A long curved incision starting halfway between the medial edge of the scapula and the second thoracic spinous process sweeps downwards and medially to pass below the angle of the scapula to the front end of the fifth rib the incision is deepened to the fascia overlying the rhomboid muscles and the trapezius bleeding points in the skin are seized with artery forceps which are then touched with diathermy coagulation With the scalpel the auscultatory triangle is opened and then the muscles are divided up to the second thoracic spinous process level and forward to the costal cartilage with the cutting diathermy point after skin towels have been affixed to the skin edges. Several large vessels require ligation with silk or thread the remaining bleeding points being sealed by diathermy coagulation. (The twitching of the muscles produced by the application of the diathermy point may be abolished by the use of intramuscular ½ per cent novocaine if curare is not being used) After this wide muscular division, the scapula is lifted off the chest wall by a scapula retractor and the second rib is identified to enable the operator to count down from this to the fifth or sixth either of which can be selected for resection the periosteum of the rib is divided from the transverse process of the thoracic vertebra to the costal cartilage in front and is elevated from the rib by a combination of rib periosteal rugine and Doyen's raspatory The rib is resected from the transverse process to the costal cartilage the section being effected by Tudor Edwards's costotome or Bethune's rib shears The pleural cavity is opened by an incision through the posterior bed of the periosteum and the parietal pleura this incision is made cautiously in case the underlying lung is adherent if no adhesions are present the chest is spread widely by a rib spreader of the Tudor Edwards or Price Thomas type (see Fig 48) If the lung is adherent it must be separated by a combination of scalpel or scissor dissection this is greatly facilitated by having a chest light in the thorax and holding it behind the adhesions to be sectioned if the adhesion is dense it is often wise to strip the adherent lung in the extrapleural plane over the area of fixation As soon as the chest is opened widely the question of operability is assessed the hilum cannot be properly inspected until the apex of the lung has been held down in a moist saline swab so that on the left side the aortic arch is clearly seen and on the right the azygos vein beneath these two structures the state of the upper hilum area can be inspected by sight

and palpation. Mediastinal invasion does not preclude resection, for the pericardium can be opened widely and an estimate made of the possibility of ligation of the pulmonary arteries and veins; nor does involvement of the tracheo-bronchial or other mediastinal glands prohibit resection, for these may often be removed *en bloc* with the lung. Before commencing the resection it is important to make sure that the inferior pulmonary vein can be isolated either within or without the pericardium; the glands surrounding this vein are often invaded and the vein itself may be occupied by growth.

If the case is operable and there are no mediastinal extensions an extrapericardial resection is proceeded with.

Should the pulmonary artery, the pulmonary vein or the main bronchus be secured first? The early exposure and temporary clamping of the bronchus has the undoubted advantage of minimizing any risk of bronchial secretions spilling over from the affected side into the underneath, sound lung, or of causing blockage of the anaesthetic airway; but this danger may be prevented by artificially occluding the affected bronchus by the use of a Thomson blocker; the blocker, however, cannot be placed when the tumour is a high one reaching almost up to the carina and then it is wiser to secure the bronchus before proceeding with the dissection of the main pulmonary artery. The advantages of early ligation and division of the artery are that a better exposure of the bronchus is possible and because it enables the inferior tracheo-bronchial glands to be dissected down before the bronchus is clamped or divided high up against the trachea.

Because of the danger of tumour masses being displaced into the pulmonary vein, draining the affected lobe or of metastatic fragments being swept on into the circulation, Allison has recently advocated the ligation of the vein as the first step in the operation.

But each operation must be planned according to the existent conditions and if there is a danger of the infected bronchial secretions being spilt over into the sound side the bronchus should be secured at the first stage of the intrapleural procedure. It may be said here that the face-down position of Overholt or Sellors facilitates access to the bronchus whereas the dorsal position associated with an anterior approach makes the early definition of the bronchus more difficult.

The isolation and division of the pulmonary artery. This is easier on the left than the right side because of the greater length of the vessel and because there is no overlapping superior vena cava.

The left-sided ligation. With the apex of the lung held well down in a moist saline swab, the mediastinal pleura lateral to the phrenic nerve is opened widely over the whole lung hilum so that the pulmonary artery and the superior pulmonary vein are well seen; at the upper end of the mediastinal incision the line of exposure curves outwards over the aortic arch and then behind the hilum so that the main bronchus is exposed behind the anteriorly placed main pulmonary arterial stem. The loose areolar tissue that lies deep to the pleural membrane is brushed aside by pledglet dissection, which should be done thoroughly so that a good length of the artery is cleared; this loose tissue often contains small blood vessels especially near lymphatic glands and these are divided between forceps and tied with fine thread or silk. Many strands of the anterior pulmonary nervous plexus require division before the true sheath of the pulmonary artery is seen and opened; between the pulmonary and the superior pulmonary vein there is a pericardial extension of dense tissue which is carefully divided; it is the fold over the obliterated vestigial vein of Marshall. The sheath of the artery is thoroughly cleared of areolar tissue within its sheath by a combination of fine scissor and pledglet dissection before a curved blunt-pointed forceps of the Moynihan cholecystectomy type is slowly and deliber-

itely insinuated behind the vessel The whole aim is to clear the vessel thoroughly as a clumsy premature attempt to pass the forceps before this has been done may tear the posterior wall of the vessel especially if growth from the bronchus has spread into the loose tissue around the vessel

A strong thread ligature or silk ligature mounted on long forceps is held down to the open jaws of the forceps and brought round the vessel and securely tied as medially as possible (Fig 12 15 (*a*)) This manœuvre is repeated and a second ligature tied as laterally

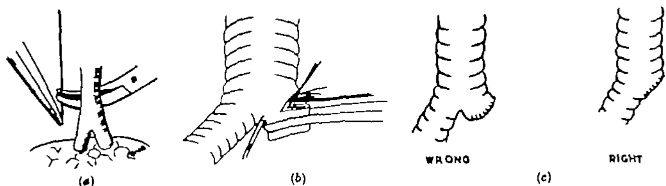


Fig 12 15 —Diagrams of pneumonectomy

(*a*) Ligature being held down to forceps behind the artery
(*b*) Division of bronchus and start of suture
(*c*) Bronchus sutured.

on the lung end of the cleared vessel as possible Before division of the vessel it may be wise to transfix the artery with a fine thread ligature on a needle for additional security the artery is then divided

The right sided artery The mediastinal pleura is widely opened as on the left side close to the anterior border of the superior vena cava which is then retracted medially by the use of two curved forceps holding pledglets As the stem of the right pulmonary artery appears shorter because of the overlap of the superior vena cava this mobilization of the great vein enables a reasonable length of artery to be exposed preparatory to its ligation. To produce an extra length the two main branches of the artery may be secured laterally and separately so that the division can be made to leave the proximal stumps of these vessels on the mediastinal end of the divided artery

The superior pulmonary vein This is dealt with either at this stage or after the bronchus has been secured On the right side the upper branch of the vein usually overlies the artery and is separated from it by a marked fibrous pericardial extension which requires division it is often helpful to secure and divide this branch before the main artery is exposed

The superior pulmonary vein is dealt with in the same way as the artery and the ligature on the mediastinal end may be supplemented by a transfixion stitch placed more laterally before the vein is actually divided

The bronchus The loose tissue parts of the posterior pulmonary plexus and the glands around the main stem bronchus are cleared by scissor and pledglet dissection the wall of the bronchus on all aspects should be cleared thoroughly before curved forceps are passed behind it The bronchus should be cleared right up to the carina and this involves a deliberate exposure of the lateral wall of the trachea The bronchus must be divided close to the trachea so that no avascular blind stump is left if an undue length of bronchus is left a bronchial stump fistula is more likely to develop than if it is divided close to the trachea

attention to this point encourages sound bronchial healing more than the choice of method of bronchial closure or the adoption of special suture material A sutured bronchial stump that is flush with the trachea falls away into the loose tissue of the mediastinum where it rapidly acquires a local investment of surrounding adventitious tissue (see Fig 12 15).

Should the bronchus be sutured behind a clamp or should an "open" bronchus be closed? The many published methods of the technical closure of the bronchus indicate that no single perfect technique has been elaborated, the high division of the bronchus is probably the most important point in avoiding fistulous formation If the bronchus is held in crushing clamps and divided between them, the devitalized tissue in the upper clamp is in a poor condition to hold sutures, single or continuous, passed through its wall above the clamp. If only one clamp is employed and the bronchus is deliberately opened above it, interrupted sutures can be placed through the cut open end as the division proceeds and this does not impair the vitality of the tissue so much as when the sutures are passed above a clamp (Fig 12 15 (*b*)) The disadvantages are that the anaesthetic gases may escape through the open bronchus with some temporary uneasiness and blood may enter the open bronchus, but both of these can be controlled readily

The bronchial blood vessels should not be damaged beyond the line of section. This advice, though good, is not always possible to follow in total pneumonectomy for cancer when the removal of the glands above the point of section often involves damage to the main bronchial vessels The object always should be to suture a stump that is viable, the open bronchus technique should be used so that no crushed dead tissue is included in the sutures, which should be of interrupted non-absorbable material (90 thread, 00 silk or stainless steel) As far as possible the sutures should be so placed as to neutralize the bow action of the cartilaginous rim which keeps the rim patent, the suture should bring the membranous part to the concavity of the cartilage rim Many surgeons resect the last cartilaginous ring but in this procedure there is considerable risk of making the remaining cuff of tissue avascular and damaged

The reinforcement of the bronchial suture line Many attempts have been made to reinforce the line by using local mediastinal tissue, by the fastening of an intercostal bundle with its underlying pleura which is then sutured to the bronchus or by the use of a large pedicled pleural flap The latter method is simple and gives good results On the left side the pleural flap is dissected off the chest wall over a wide area, the upper limits being well above the aortic arch and the lower limit being to the sixth rib A square of pleural membrane with its base attached over the aorta is turned down on to the bronchial stump three sutures that have been passed through the bronchus stump and were left uncut after the closure had been completed have both ends re-threaded on to small curved needles and are passed through the flap in appropriate sites so that when tied they hold the endothelial surface of the flap snugly on to the bronchus, which has been covered with penicillin powder. The flap is then loosely attached at its periphery by a few fine sutures to the surrounding mediastinal tissue, all "tenting" being avoided

On the right side the flap is dissected well above the azygos vein

The inferior pulmonary vein It is often easier to expose this from the posterior aspect The lung is held upwards and medially and is kept on the stretch while the pleura is opened widely from the lower end of the previous incision into it made to expose the bronchus, to well beyond the lower border of the vein which is readily seen at the upper end of the ligamentum latum pulmonis The loose areolar tissue around the vein is cleared and its proper sheath opened before the ligature is passed round it After this vessel has been divided the lung is free except for its attachment to the ligamentum latum which is then

divided close to the mediastinum the ligament always contains vessels which require clamping and ligation As much tissue as possible is removed as there are always lymphatic glands present, especially in the region of the inferior pulmonary vein

The completion of the operation The phrenic nerve is isolated as it lies on the pericardium and a segment of it removed Price Thomas does not divide the phrenic on the left side because of the risks of gastric disturbances that may follow in some patients Ligatures are required on both ends to secure the accompanying blood vessels After haemostasis has been established the chest is closed in layers without drainage penicillin powder or liquid being left in the pleural space The intrapleural pressures are adjusted to normal with an artificial pneumothorax apparatus with the patient in the supine position

Should the pleural cavity be drained? Some surgeons employ closed intercostal drainage for 24 hours but this is not essential The intrapleural pressures are more easily adjusted if there is no drainage tube the risk of infection via the tube track is abolished and the patient is more comfortable in bed In addition an air cushion is provided to support the bronchial stump during coughing Even if a tube is used fluid accumulates later in the chest and there is no evidence that less post-operative aspirations are needed in the drained than the undrained cases

Intrapericardial ligation of the great vessels in pneumonectomy This procedure was first introduced by Allison (1946) to extend the scope of the operation to include patients in whom mediastinal extension of the tumour made an extrapericardial operation impossible It is now advocated by many thoracic surgeons as being the logical operation in pneumonectomy for cancer because it provides a wide excision of the surrounding tissue and lymphatic fields and enables a more radical operation to be performed It is however followed by a higher incidence of post-operative cardiac irregularities

The operation The main thoracotomy approach is as described on page 279 The pericardium must be freely opened once the decision to use the intrapericardial technique has been made The sac is opened just in front of the phrenic nerve which is then divided the pericardium must be freely opened around the whole lung root both anteriorly and posteriorly As the superior pulmonary vein often overlaps the artery it may be secured tied and divided before the artery is dealt with the serous reflections that provide a type of mesentery to the vessel require division before the vessel can be safely encircled a transfixion stitch may be used distal to the first ligature tied near to the auricle The pulmonary artery is then cleared after division of the serous reflection on its postero-inferior surface the vessel is divided between ligatures with the added safety again of a trans fixion stitch The inferior pulmonary vein is then isolated ligated and divided

On the right side the parietal pericardium forms a bed between the superior vena cava and the right pulmonary artery and in this angle the serous pericardium is reflected on to the under-surface of the artery (Allison) When these two layers have been cut the artery can be isolated in the recess behind the superior vena cava and tied and divided *Before* these pericardial folds have been divided the artery lies in a triangular depression of which the *medial* and inferior borders are *formed* by the superior vena cava and the superior pulmonary vein (post caval recess of Allison)

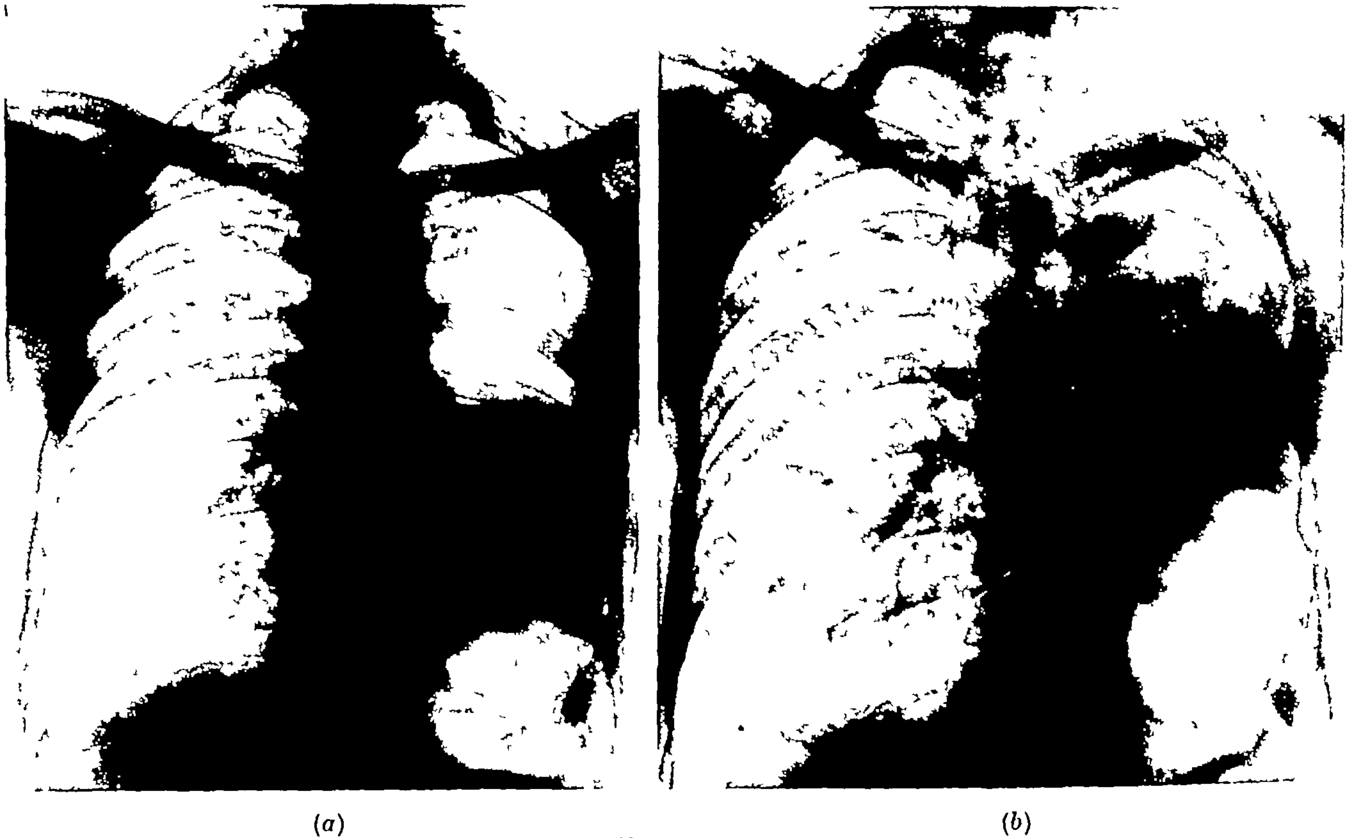
After the vessels have been dealt with the pericardium over the main bronchus is opened and the bronchus exposed and treated as in the operation of extrapericardial pneumonectomy The pericardium at the back of the lung root is then incised and the lung with the lymphatic glands from the tracheo bronchial angle with much loose mediastinal tissue and a considerable portion of pericardium removed *en bloc*

With this approach it is possible to remove a portion of the wall of the auricle in those patients in whom cancerous growth has invaded the pulmonary veins

The post-operative care of pneumonectomy has been discussed in Chapter 5, and the diagnosis and treatment of the complications outlined

Lobectomy The operative plan is as described on page 170 in the treatment of bronchiectasis, with the exception that all the neighbourhood lymphatic glands are removed

Thoracic adjustments and lung function after pneumonectomy. After total excision of one lung the remaining lung enlarges and unless active measures are adopted to prevent it, the mediastinum is pushed over to the other hemithorax, the ribs of which progressively fall inwards and become approximated with consequent diminution in the



(*a*) (*b*)

Fig 12 16

(*a*) The radiographic appearances of the chest a week after left pneumonectomy
The mediastinum is kept central by the artificial introduction of air into the pleural space

(*b*) A year after left pneumonectomy
The right lung has distended to push the mediastinum over to the left side this displacement, together with the elevation of the left leaf of the diaphragm and the formation of a fibro thorax, has obliterated the left pleural space

size of that side of the chest In time the pleural cavity on the pneumonectomy side becomes completely obliterated, the process being aided by the elevation of the diaphragm and the organization of the pleural fluid into dense fibrous tissue

That this natural process of obliteration of the dead space is not altogether satisfactory is generally accepted and constant efforts have been made to overcome the disadvantages, the chief of which are the great tendency for the remaining lung to over-distend and for the mediastinum to become grossly distorted

The methods adopted to prevent these two developments are

(*a*) Thoracoplasty

(*b*) The use of artificial pleural fillings (plasma, polythene balls and packs)

(*c*) Pneumo-peritoneum

Of these methods the most satisfactory would appear to be thoracoplasty but it is not always possible or humane to suggest this added operative burden to a patient often elderly who has successfully undergone the operation of pneumonectomy It is therefore appropriate at this stage to discuss the physiological changes that follow lung excision

Functional adaptation after pneumonectomy A clinical study of pneumonectomy patients in the immediate post-operative periods and at subsequent follow up usually at three-monthly intervals is the basis for the following points

(a) Immediately following operation the respiratory rate increases moderately but rarely exceeds 25 per minute this rarely persists longer than from three to five days and then settles around 20 a minute

(b) There is a slight increase in the depth of respiration

(c) In some 15 to 20 per cent of adults cardiac abnormalities of rhythm develop often associated with transient pulmonary oedema which settles satisfactorily in most patients

(d) Functional activity is restricted, on the average proportional to the age of the patient children being the least affected Life is however usually compatible with sedentary occupations and moderate degrees of exercise such as walking two to five miles 'at their own pace Children show little limitation in their activities and are usually able to attend school and play games with their contemporaries

(e) Vital capacities measured at intervals after pneumonectomy for carcinoma vary on an average between 1 500 and 2 000 c c and these are helpful as a rough guide to the amount of activity that is tolerated and their subjective symptoms such as dyspnoea

Respiratory physiologists have investigated limited series of patients and their findings provide the scientific explanations for the above clinical observations

1 *The minute volume respiration* is not significantly changed being compensated for by a slight increase in rate and depth.

2 *The oxygen uptake* naturally must remain approximately the same so that the remaining lung increases its uptake inversely proportional to the percentage of the total oxygen provided by that lung pre-operatively

3 *The maximum breathing capacity* is reduced but much less than might be expected it may be as much as 80 per cent of the pre-operative value explicable by the good functional co-ordination of the respiratory muscles and the increase in rate of respiration which compensates for the loss in depth.

4 *Decrease in the respiratory reserve* naturally results because of the loss in maximum breathing capacity

5 *Gas mixing is improved* because of the increase in ratio of effective tidal air to functional residual air

6 *The total lung volume* in deep inspiration is greater than an homologous normal lung explained by the absence of the opposite lung with a mobile mediastinum

7 *The pulmonary blood flow* must be doubled after pneumonectomy and is accomplished by an increase in the rate of flow or an increase in the functional capillary bed or both

8 *Pulmonary blood pressure* Cournand has demonstrated that in the course of strenuous activity very marked pulmonary hypertension occurs Theoretically this seems an excellent reason for purposely limiting activity after pneumonectomy but he states that electrocardiographic studies after several years do not reveal evidence of right ventricular hypertrophy

Finally the thoracic surgeon s main interest is centred around the possible development of true emphysema or increasing distension of the lung in full expiration and its prevention by thoracoplasty on the pneumonectomy side The answer is not available at the moment

but over-distension is not inevitable in the absence of thoracoplasty but is probably related to persisting pathological changes. Peters *et al* in an investigation of a small series of children after pneumonectomy found a high residual air in 50 per cent of his cases, but still with a good exercise tolerance. It would seem right to recommend thoracoplasty in non-tuberculous cases only where there is evidence of increasing residual air and a reduction in the maximum breathing capacity.

An interesting and important remark by Peters was that his two best results were in a gymnast and a construction worker, both of whom had made whole-hearted efforts to overcome their respiratory handicap by physical training to increase the maximum mobility of the chest wall, diaphragm and mediastinum. A further example of this has occurred in our experience, where a professional sprinter, after pneumonectomy, was able to run a hundred yards in 11 seconds.

Post-pneumonectomy emphysema. It is strange after so many years in which lobectomy and pneumonectomy have been carried out that doubt still exists as to whether the remaining lung tissue becomes truly emphysematous (i.e. with rupture and atrophy of alveoli and loss of elastic tissue) or whether the condition is one of simple lung distension even with true hyperplasia. In young children who have undergone pneumonectomy for bronchiectasis it is possible to imagine that hyperplasia and hypertrophy have followed, but in adults and especially in the older subjects who have had excision for cancer it is difficult to conceive of this happening and the remaining lung distends and becomes truly emphysematous.

Many investigations have been done to attempt a physiological assay of the changes in respiratory function and especially to try and establish whether these changes are of the order that would be expected in emphysema (Cournand and Berry, 1942; Birath *et al*, 1947).

The effect of age. As would be expected the resilient and actively growing tissue of young subjects enables extensive resection of lung tissue to be executed without gross measurable disturbance of cardio-respiratory function, and this can be noted both in experiments on young animals and in young children; but in older patients there is a considerable reduction in breathing reserve, especially with increased activity. The maximum breathing capacity is diminished, not in proportion to the diminution in lung volume so much as an alteration in the state of the remaining lung (Cournand and Berry, 1942). The remaining lung loses efficiency if it becomes over-distended. Cournand showed that thoracoplasty on the pneumonectomy side could largely prevent this over-distension of the "good" lung. But before adopting the principle that thoracoplasty should be used to obliterate the empty pleural space or pneumonectomy gap in patients who have undergone this operation it is important to point out that clinically many hundreds of these patients have lived comfortable lives for many years without dyspnoea except on rather severe exercise and that a careful physiological examination of this type of patient (Birath and Crafoord, 1947) has shown that the expected disagreeable effects are not so severe as would be expected. They based their findings on patients two to twelve years after operation by investigating the total lung volume and its fractions, the estimation of the efficiency of the ventilation by reference to the respiratory dead space, by a determination of the blood gases and by general clinical findings. The lung ventilation was obviously worsened with an absolute and relative increase in the respiratory dead space due largely to the increased lung inflation and possibly to emphysema, but dyspnoea, though present immediately after operation, steadily diminished later and they feel that even if emphysema develops slowly it encroaches very little on function.

In this country thoracoplasty is not used widely as a method of obliterating the pneumonectomy gap after operations for cancer but is frequently employed after total lung excision in cases of pulmonary tuberculosis where it is undesirable to allow the 'good side' which has usually been the site of tuberculous infection to over-distend

The use of artificial pleural fillings Certain plastic materials such as polythene have been used to fill in the pleural space after pneumonectomy they are not irritant to the tissue and slowly become encapsulated in thin fibrous tissue Surgical reluctance to use foreign bodies has however restricted their use except in a few clinics and private conversations not infrequently elicit a story of mishaps usually associated with infection and wound disruption

Phrenic paralysis and pneumo-peritoneum After pneumonectomy it is customary to resect a portion of the phrenic nerve in the thorax before closing the chest and the subsequent elevation of the diaphragm assists in decreasing the size of the space The rise of the paralysed leaf may be accentuated by the use of a pneumo peritoneum (Fig 12 17)



Fig 1 1 —Left post pneumonectomy space after phrenic nerve paralysis and pneumo-peritoneum, three months after operation

This method has not gained great popularity but is of considerable value when used thoroughly if the diaphragm is to be elevated to a high level it is important to start the pneumo peritoneum early after operation before it becomes fixed by organization of the inevitable overlying haemothorax

PRIMARY MALIGNANT TUMOURS OF THE LUNG OTHER THAN CARCINOMA

The rarity of malignant tumours of connective tissue origin justifies the briefest mention of them, however interesting the individual case may be. Fibro-sarcoma is occasionally encountered. Ball (1931) found 13 examples in the literature from 1900 to 1931. These tumours, as in sarcoma elsewhere, may be small round-celled, large round-celled, or spindle-celled sarcoma and a slow-growing type of fibro-sarcoma exists which may be seen developing in the bronchus more commonly or in the lung parenchyma. Carswell and Krafft (1950) in reporting a patient with a fibro-sarcoma of the bronchus treated by pneumonectomy stated that 31 examples of primary sarcoma of the lung had been reported in the American literature and that there were only 6 described as being primary in the bronchus. In the same year Black (1950) and Curry and Fuchs (1950) each described a bronchial fibro-sarcoma. Curry and Fuchs' patient actually expectorated the tumour. She was a girl of 13 who was well four years after this incident. An instance of a malignant myo-sarcoma is given in Fig. 12.20 (*b*).

Tumours of the trachea

These are rare, the commonest being carcinomatous, though adenoma, fibroma and submucous lipoma have been reported. Secondary involvement from cancer of the thyroid gland and of the cervical oesophagus are commoner than primary malignant disease. Haemoptysis and respiratory obstruction are the symptoms that lead to an endoscopic examination when the tumour is seen and biopsy examination carried out.

Treatment has been by partial endoscopic removal supplemented sometimes by deep X-ray therapy and by excision of the trachea, followed either by permanent tracheotomy or by reconstruction of the trachea. Belsey (1946) was the first surgeon to excise and reconstruct a trachea; the tumour was stated to be a cylindroma which he regards as a separate condition from bronchial or tracheal adenoma; by the ingenious use of stainless steel wire combined with fascia lata he restored functional continuity. Rob and Bateman (1949) have restored the tracheal airway by using tubes of tantalum gauze covered by fascia lata. The success of the method depends largely on the rapid regeneration of tracheal epithelium that is known to occur; this replaces the temporary graft provided by the fascia lata, the tantalum gauze remaining as a permanent splint that maintains the tracheal lumen. Satisfactory reconstruction is only possible if one recurrent laryngeal nerve and one superior laryngeal nerve can be preserved; if both sets of nerves are sacrificed the airway will be obstructed because of the bilateral cord paralysis. In the absence of both lower nerves the sensory denervation that follows the loss of both superior ones will be followed by inhalation of food into the tracheo-bronchial tree leading to septic aspiration pneumonia.

Benign and border-line tumours of the lung

The classification of innocent lung tumours remains unsatisfactory because many reported "tumours" are in fact examples of masses of tissue, developmental in origin and giving rise to formations of epithelial and mesodermal cells. These are frequently grouped together under the clumsy and misleading term of "hamartoma". Such malformations include the arterio-venous fistula of the lung (pulmonary telangiectasis, haemangioma of the lung—see p. 28) and possibly the condition of "chondroma", pulmonary haemangio-fibroma, haemangio-endothelioma (Tudor Edwards and Brian Taylor, 1938).* There is no

* Pleural mesothelioma or endothelioma may arise from the parietal or visceral layer of the membrane.

evidence that the true hamartoma undergoes malignant transformation but at the most there is little clinical chance of diagnosing their exact histology and nature until they have been resected after diagnostic thoracotomy

Hamartoma These tumours are usually sited in the lung parenchyma and do not form really circular masses as their edges are often irregular hence their confusion with infiltrating peripheral carcinoma on radiological appearances They consist usually of all elements of the bronchus with cartilage muscle and epithelial elements Frequently they contain cystic spaces and the cartilaginous portion may ossify or calcify Quite exceptionally a mass of cartilage cells may project into the lumen of a bronchus and be seen and removed at bronchoscopy such endobronchial tumours may well be examples of true chondroma

The peripheral hamartoma may cause symptoms by obstructing a bronchus the last one I removed lay in the right main fissure and had produced atelectasis of the right middle

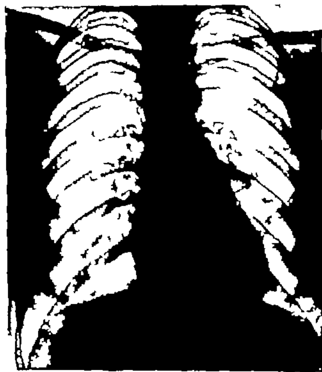


FIG 12 18.—Mass radiography of symptomless tumour *near left hilum*

Female aged 24. At thoracotomy the mass lay in the main fissure from which it was dissected free Histological examination revealed typical thymus tissue

lobe the presenting symptom being haemoptysis The particular lobectomy done was difficult technically because of the mass that overlay the hilar vessels this was removed under the impression that it was a large lymphatic gland but subsequent histology disclosed a hamartoma

A simple example of the difficulties may be in tanced

Miss M aged 24 had no symptoms the tumour shown on the radiograph in Fig 12 18 was disclosed by *mass radiography* *It was impossible to make an exact pre operative diagnosis* thoracotomy was employed and a tumour resected from the main left fissure The histological examination of the mass revealed normal thymic tissue the result presumably of an aberration of development She remains well and symptomless five years after the resection The indications for exploratory operation in symptomless lung tumours will be discussed later



FIG 12 19 —Left lower lobectomy specimen removed from a man of 32

The only symptom was haemoptysis A radiograph showed segmental collapse of the left posterior basal segment The tumour was seen easily at bronchoscopy Pathological report by Professor Orr described a leio-myoma

The tumour is seen arising from the bronchial wall just below the origin of the segmental bronchus to the "dorsal lobe" (apical segment of lower lobe)



FIG 12 20 —Rounded tumour in left lung symptomless

At thoracotomy the tumour had invaded upper and lower lobes The histology was squamous carcinoma of bronchus



FIG 12 21 —Radiograph showing a tumour of the left lung in a man of 62

This was regarded as a peripheral carcinoma After resection by lobectomy this tumour histologically was a myoma with sarcomatous degeneration and the tumour had invaded the surrounding lung tissue

Other innocent tumours Apart from hamartomatous formation lipoma fibroma neuro-fibroma zanthoma and myoma have been described an unusual leimyoma of the left main bronchus causing atelectasis of the left lung has been reported by Turkington *et al* (1950) the patient a woman of 57 remained well after a left pneumonectomy I have done a left lower lobectomy for a similar tumour (Fig 12 19)

The exact diagnosis of many innocent tumours remains obscure until they have been removed at operation the discovery of a circular possibly lobulated tumour often symptomless by routine radiography or by the mass miniature radiography method creates at once a feeling of diagnostic uncertainty Because such tumours may be malignant bronchial growths (Figs 12 20 and 12 21) the general opinion is that excision should be practised and the disadvantages of resecting what may be an innocent condition are much outweighed by the fact that many of these circular shadows owe indeed their presence to a malignant tumour It is however important not to resect a whole lung for a simple tumour such as a hamartoma the decision to employ a lobar or even a segmental resection instead of pneumonectomy may well depend on a frozen section biopsy done at the time of operation If doubt still exists and the surgical opinion is that the condition is innocent the lesser resection should always be practised for there is evidence that lobectomy for peripheral malignant tumours is as effective as pneumonectomy

Bronchial adenoma Of all lung neoplasms adenoma provides about 4 per cent they present striking differences from bronchiogenic carcinoma and it is increasingly difficult to accept Womack and Graham s thesis that they are all malignant tumours The main objection to their classification as malignant tumours rests on their clinical behaviour rather than on their microscopical appearance They develop in a younger age group often in the late 20 s affecting women more commonly than men in sharp distinction to bronchial carcinoma and are associated with a long survival even in the absence of effective treatment

At the same time it is not altogether reasonable to classify as innocent a tumour which occasionally passes beyond the normal barriers of restriction and becomes locally invasive or even infiltrates lymphatic glands to behave much as certain mixed salivary tumours do It develops presumably from the mucous glands of the bronchus and not from the surface layer of mucous membrane It causes serious symptoms and often prolonged illness chiefly the result of bronchial obstruction though it may become a large tumour when growing out into the periphery of the lung before causing serious effects

Foster-Carter (1941) reported 70 examples of whom 62 per cent were in women and in the whole series a long survival was the rule in the presence of what might now be considered inadequate treatment In my own small series with Brian Taylor there have been 19 of whom 10 were women and the average age was 30 one of these patients survived for 30 years after the initial haemoptysis at the age of 21 and in whom no more radical treat ment than diathermy and radon seed implants had been employed In this group of 19 patients 9 have been subjected to what we consider adequate surgery the latest was operated upon 2 years ago and all except one are surviving—a picture very different from that seen after resection for bronchial carcinoma

Exceptionally invasive tendencies are present and local lymphatic glands may be involved as in the only case of bronchial fistula that developed in our series of 9 resections There are records in the literature of one or two patients in whom adenomatous ' deposits have been found as liver metastases but on the grounds of these exceptional patients it hardly seems fair to incriminate the larger group as carcinoma as this assumption would suggest that all these patients should be subjected to radical pneumonectomy with unjusti

fiable sacrifice of functioning lung tissue The invasive tendency in some of the tumours has been stressed by Womack and Graham (1938 and 1942) and Adams *et al* (1942)

Pathological features The tumour most commonly arises in a main or lobar bronchus * It is a well-defined, lobulated mass usually varying from 1–5 cm in diameter, attached by a broad base to the bronchial wall Although commonly described as having a larger extrabronchial than intrabronchial formation, a careful examination of the tumour usually shows a thinned-out shell of cartilage over the periphery of the mass that projects into the lung parenchyma (Fig 12·23) The portion that projects into the lung tissue is, however,



Fig 12·22 —Biopsy of bronchial adenoma from patient known to have the tumour for 30 years

Note the intact mucous membrane, overlying the masses of tumour cells, at the right-hand side of the section



Fig 12 23 —Right lower lobectomy specimen

Adenoma arising from the segmental bronchus to the apex of the lobe The main lower lobe bronchus is compressed the main mass of the tumour projects into the lung tissue but is actually separated from it by a false capsule formed of a rim of compressed cartilage The main symptoms were haemoptysis and pyrexia Specimen 8 cm wide (Dr A M Nussey's patient)

almost invariably larger than that seen in the bronchial lumen When viewed bronchoscopically the tumour may be red and vascular

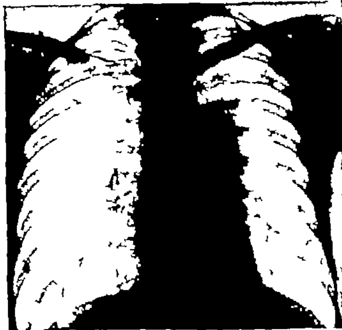
Occasionally the tumour may be a large mass in the periphery of the lung, having arisen from a smaller bronchus

Histology The cells are regular in appearance, often with a well-defined tubular formation, the appearance is one of great cellularity The interpretation of the section is not easy and the arrangement of the cells may be quite disorderly Very great experience is necessary before a histological diagnosis of " adenoma " can be made (Rabin and Neuhof, 1949) There is often evidence of mucous secretion and this supports the theory that the tumour develops from bronchial mucous glands, this is further suggested by the noted

* A few recorded cases have established that the tumour may arise in the trachea or even involve both main bronchi



(*a*)



(*b*)

FIG 12.24

(*a*) Woman of 30 Peripheral type of bronchial adenoma Symptomless
At this time thoracotomy was refused by the patient.

(*b*) 11 months later
Patient ill, pyrexial and toxic. The left upper lobe has collapsed.



FIG 12.24 (*c*)—Tumour after upper lobectomy
The mass is partly cystic It remains well encapsulated and the histology is that of bronchial adenoma length 13 cm
Patient well and symptomless three years after lobectomy

comparison with the mixed salivary tumour, in this suggested similarity the common features of mucoid material and of cartilage are also stressed. The tumour is invariably covered by normal bronchial mucosa, which adds further to the impression that it arises from the submucosal area and not the bronchial lining mucosa (see Fig 12 22). Local metastasis to a lymph gland is unusual but does happen: in a few exceptional cases metastases have been found in the liver.

Clinical features. Although haemoptysis is the earliest and most prominent feature, the frequent complaint of the expectoration of purulent sputum and of pyrexia indicates that the bronchial obstruction produced by these tumours causes infection in the collapsed bronchiectasis beyond the obstruction. Most of the patients seen in a thoracic clinic have atelectasis (Fig 12 26), and a few have lung abscess. Before the widespread use of bronchoscopy a number of the patients had spent long fruitless days in a sanatorium in spite of a



FIG 12 25.—Male, aged 30. Large tumour (15 cm) in right upper lobe with an intrabronchial projection easily seen at bronchoscopy.

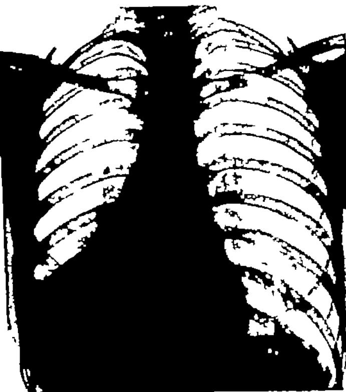
The tumour has eroded rather than infiltrated the bronchial wall and the lung parenchyma. A circular tumour was noted on the radiograph five years before this was removed by operation; a year and a half before operation he started to have small *haemoptyses*. *There* were no glandular invasions. Prof J W Orr kindly examined this tumour and from the histological appearances reported it to be "a *mucous-secreting* adeno carcinoma clearly resembling a salivary tumour type; the tumour alveoli consist partly of tubules containing *mucus* and partly of cribriform structure. Although the tumour is so circumscribed to the naked eye there is a diffuse infiltrative edge microscopically and I think one must regard this as a malignant tumour."

persistently negative sputum. When the lobe collapses a sudden pyrexial illness may develop and be treated as pneumonia with relief of symptoms as the result of antibiotic therapy. In such patients the clinical and radiological detection will lead to bronchoscopy or bronchography and the cause of the obstruction will soon be clear.

Haemoptysis without radiological features may be present and only bronchoscopy will reveal the true nature of the disease.

Mrs R, a woman of 40, had suffered from repeated haemoptysis for two years; the radiograph was normal. Bronchoscopy revealed a tumour involving the left main stem bronchus. This was treated by excision of the main stem bronchus followed by end to end anastomosis.

A mass may be found in the chest on routine radiological or miniature mass radiography without haemoptysis, though cough is a common feature.



(a)



(b)

FIG 12 26

(a) Woman of 23 Collapse of right lower lobe Emphysema of right upper lobe
Bronchoscopic biopsy adenoma

(b) Radiograph of same patient four years after bronchoscopic removal and radon therapy
The lower lobe is completely re-aerated (Dr A. Brian T ylor patient)



(a)



(b)

FIG 1* 2

(a) Photograph of a [illegible] of left main bronchus.
Symptom of haemoptysis in woman of 40 with a normal radiograph of the chest bronchoscopy revealed adenoma of left main bronchus. This was treated by resection of the bronchus and end-to-end anastomosis (d [illegible] and [illegible] [illegible] J Surg)

(b) Radiograph of the chest two years after resection of the left main bronchus for tumour shown in Fig 1* 2 (a).

Bronchography The detection of bronchial tumours by lipiodol bronchography is not often employed, as bronchoscopy gives an opportunity to examine the tumour and perform a biopsy . the tumour, however, may be demonstrated as the cause of a bronchial obstruction by bronchography If it projects into the lumen of the bronchus as a dome-like mass the lipiodol will delineate this convexity but the sign is not diagnostic as a malignant tumour projecting into a bronchus may provide identical appearances , nor is it by any means present in most bronchial adenomata

Treatment In view of the good prognosis to life as far as the purely neoplastic nature of the tumour is considered, efforts should be made to employ conservative but effective measures Because the tumour will produce severe lung damage such as bronchiectasis or chronic lung abscess, in the great proportion of patients it should be removed Before structural damage has developed beyond the tumour there is an increasing tendency to resect it by strictly local excision such as bronchotomy or bronchial wall excision (Crafoord, 1949 , Price Thomas, d'Abreu and MacHale) If the occlusion of the lobe has been followed by irreversible bronchiectasis, lobectomy or pneumonectomy will be required In a study of the literature it is obvious that delay in recognition and treatment has led to many more pneumonectomies than is desirable, but total bronchiectasis is certainly an indication for this major resection Less radical measures such as bronchotomy, or segmental or lobar resections, are being practised as knowledge of the behaviour of this tumour becomes better known

Attempts to destroy the tumour by diathermy or radium are being abandoned because of the incomplete nature of the extirpation obtained A study of lobectomy specimens often shows that the large extrabronchial portion of the mass is beyond the range of broncho-scopic removal, which should be reserved for palliative relief of bronchial obstruction to allow the expectoration of pent-up distal bronchial secretions in the aged or as a preparation for lobectomy or pneumonectomy Any thoracic surgeon who has had experience in resecting lobes or lungs, the seat of bronchiectasis after failed bronchoscopic removal or radiation therapy, is not likely to underestimate the difficulty of dissecting the hilum of the lobe or lung after this ineffective therapy which is so productive of dense peri-vascular and peri-bronchial fibrosis Bronchoscopic removal, however, will always retain a small place as a method of temporarily relieving bronchial occlusion and in patients who refuse more major surgery it may be astonishingly efficacious, as in the patient illustrated in Fig 12 26

This woman, aged 33, was and is under the care of Dr A Brian Taylor She was first seen by another physician in 1943 at the age of 25 complaining of cough, bronchitis and slight asthma the radiograph showed a collapsed right lower lobe In 1944 Dr Taylor bronchoscoped the patient and saw a vascular tumour filling the lower part of the right main bronchus, a biopsy from which revealed the histological features of adenoma The tumour was treated by diathermy and radon seeds in a Tudor Edwards container The lower lobe re-expanded but in 1945 a return of haemoptysis occasioned a further bronchoscopy at which a small tumour mass was seen this was treated by further radon treatment. She has remained completely well for the following five years, is symptomless with a normal radiograph, and at full work.

Bronchoscopic methods can undoubtedly relieve symptoms by checking the bleeding and by reopening a bronchus that has been occluded But criticism may be made that incomplete removal of a tumour that may become malignant is dangerous and may cause broncho-stenosis with resultant severe bronchiectasis accompanied by persistent haemoptysis and the expectoration of purulent sputum For these reasons resection of the tumour is preferable to bronchoscopic removal

Operative procedures

I Local resection of the involved area of the bronchial wall
II Lobectomy
III Pneumonectomy
IV Bronchoscopic treatment

The selection of the operative procedure depends on the site and size of the tumour and of the effects it has produced Evarts Graham (1938 1942 1949) has adopted the view based on pathological and clinical studies that pneumonectomy is the correct procedure for a tumour that spreads to lung tissue and also to lymph glands most thoracic surgeons prefer a lobectomy unless the tumour involves the main stem bronchus in such a site that lobectomy would not adequately remove the tumour or remove the effects such as bronchiectasis which may have involved both lobes of the lung Resection of the bronchial wall is preferred if the tumour lies in the main bronchus and has not produced irreversible changes in the lung such as bronchiectasis or lung abscess

Rabin and Neuhof (1949) reviewed 308 cases from the world literature there were 43 lobectomies without lymph gland involvement and pneumonectomy in 60 instances 13 of which had lymph gland metastases at autopsy on 23 tumours the glands were invaded in 5 In the whole series there were 3 remote metastases but no example was seen exhibiting typical malignant extension. These authors favoured local bronchoscopic removal and the account of their own 64 cases certainly produced good follow up evidence of the safety and efficiency of this treatment Nevertheless the equally good results from lobectomy incline to favour the more radical procedure which should certainly be employed if bronchiectasis has developed distal to the tumour Rabin and Neuhof themselves prefer lobectomy when the tumour is in the upper and middle lobes or in a basal bronchus because such sites place the tumour out of reach of full bronchoscopic eradication Most of the patients that reach the surgeon have irreversible bronchiectasis and lobectomy or pneumonectomy will be necessary

Resection of the tumour by bronchotomy Complete removal of the extrabronchial extension through a bronchoscope is unlikely if the tumour is diagnosed by bronchoscopy performed for haemoptysis and in the presence of a normal radiograph of the chest direct exposure of the bronchus by thoracotomy followed by excision of a portion of the bronchial wall may be justifiable and has been performed by Price Thomas and others with good results The main stem bronchus may be excised and reconstituted by end to-end anastomosis

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PART V

THE SURGERY OF THE MEDIASTINUM

CHAPTER 13

SURGERY OF THE HEART GREAT VESSELS AND PERICARDIUM

After Rehn (1897) successfully operated on a cardiac wound progress in cardiac surgery was slow with intermittent brilliant adventures such as the surgical relief of constrictive pericarditis attacks on aneurysm (Power and Colt 1903) valvulotomy for mitral stenosis (Souttar 1925 Cutler 1929) 1939–49 was a decade of spectacular progress beginning with the surgical closure of the patent ductus arteriosus simple or infected (Gross and Hubbard 1939 Tubbs 1939) the excision of the stenosed area in co arctation of the aorta (Crafoord 1945) and proceeding to the brilliant Taussig Blalock operations for congenital cyanotic disease (Blalock and Taussig 1945) Brock s direct surgical attack on stenosis of the pulmonary artery or its infundibulum (1948) and the designing of further operations by Blalock and Taussig for the relief of some of the very complex cardiac malformations such as complete transposition are examples of continuing research and endeavour

The surgical closure of septal defects has been tackled (Murray 1948) but the most valuable operations of all have been the surgical relief of certain forms of mitral stenosis (Harken 1950 Brock 1950 Bailey 1950) in the last few years

Determined efforts are being made to develop extracorporeal types of circulation which would enable cardiac operations to be executed while a mechanical apparatus takes over the functions of the heart and lungs This has been achieved successfully in dogs by methods necessarily complicated and involving operations and technical procedures of great magnitude (Gibbon 1937 1950) Experimentally in dogs Sewell and Glenn (1950) have diverted blood from the right side of the heart by means of an artificial pump which delivers blood from both venae cavae to the pulmonary artery The many papers referred to by Stokes and Gibbon in their article in 1950 showed the widespread interest being taken in this problem Important work is also being done in the laboratories by Bjork (1948) and Jongbloed (1948)

Surgery in acquired disease of the heart

A considerable variety of conditions are amenable to surgical treatment at certain phases of the diseases These include (1) pericardial effusions and infections (2) constrictive pericarditis (3) valvular stenosis (4) cardiac wounds (5) cardiac ischaemia (6) tumours and cysts of the heart (7) aneurysms of the aorta

The story of many survivals of serious cardiac wounds with or without surgical treatment and the recent operations for mitral and pulmonary valve stenosis indicate that the heart muscle can tolerate considerable injury the dramatic account of the first successful suture of a cardiac wound (Rehn 1897) is excelled by the successful removal of many foreign bodies from the heart by Lt -Col. Harken (1946) of the United States Army it seems impossible to better this performance and without doubt his intrepid spirit has emboldened

others to apply the lessons of war surgery to civilian cardiac surgery and he himself has been a leader in this field Increasing confidence in the use of surgery is illustrated by a rational treatment of pericardial effusions whether serous or infected exact clinical recognition of compression produced by pericardial effusion, whether complicating severe rheumatic, septicaemic or tuberculous infections, has been followed by insistence on decompressive measures by needle aspiration or surgical drainage The treatment of the chronic form of constrictive pericarditis in which the heart is progressively strangled by the natural contraction of fibrous tissue has become logically direct, chiefly in response to the thoughtful work of Churchill (1936), and pericardiectomy has replaced attempts to provide relief by resection of the cartilaginous framework overlying the heart in the hope that the embarrassed heart would thereby be relieved, an operation based on anatomical and not physiological reasoning

Real progress in the treatment of cardiac ischaemia, the result of coronary artery disease, has been slow in spite of painstaking research by Beck (1935) and O'Shaughnessy (1936) But the efforts to improve the cardiac blood supply by grafting operations, using the lung or omentum, at all events showed that the most crippled cardiac patient could survive major surgical operations with surprising comfort The relief of cardiac pain by resection of the sympathetic nervous system has probably been used inadequately and at the moment this approach is probably the chief surgical contribution that can be offered, in selected cases, to those afflicted by persistent cardiac pain Great interest is being shown in the study of patients who have been subjected by Beck to his operation of anastomosing a systemic vessel to the coronary vein of the heart after its ligation proximal to the coronary sinus

The relief of mitral stenosis by surgery has undoubtedly become the most important cardiac operation and large numbers of patients are being operated on at the moment of writing

DISEASES OF THE PERICARDIUM

Pericardial infections

Rheumatic inflammation provides the commonest disease of the pericardium Its exudative reactions resolve in recovering patients with the production of minor or gross pericardial thickenings which may partially or wholly obliterate the pericardial sac Such adhesion formation does not produce true constrictive pericarditis and post-mortem experience in rheumatic heart disease shows that most extensive pericardial changes fail to limit cardiac dilatation Although it is possible that cardio-pericardial adhesions may interfere with the heart s action, the assumption that dilatation and failure of the heart resulting from the pulls and stresses of such bands might be relieved by surgical operations which freed the overlying, often retracted chest wall (Brauer's cardiolysis) is no longer held (Brauer, 1902) This operation was applied, with doubtful results, to patients with rheumatic heart disease associated with cardiac failure, a tumultuously beating heart, and retraction of the chest wall In modern practice the only operations performed for the release of the chest wall are for cardiac displacement, the result of a gross funnel chest deformity (see Chap IV)

Effusions

Surgical relief of acute cardiac embarrassment due to fluid pressure may be required in (1) rheumatic pericardial effusions, (2) tuberculous pericarditis, (3) pyogenic pericarditis, (4) cardiac tamponade due to trauma

Whether the heart be compressed by fluid, pus or blood, with or without associated air, the clinical features are the same. Beck's triad provides the best clinical evidence. Beck (1937) indicated that acute cardiac compression provides some features quite distinguishable from chronic constriction. The acute triad consists of a rising venous pressure, a falling arterial pressure and a small quiet heart.

As compression is sudden the veins have not had time to stretch in spite of the rise of venous pressure caused by the compression of the heart and the venae cavae; the fall in venous return will, of course, lead to a decrease in cardiac output providing signs of arterial failure with the clinical features associated with anoxaemia—skin pallor, feeble pulse (which may show pulsus paradoxus), an anxious expression and attacks of fainting.

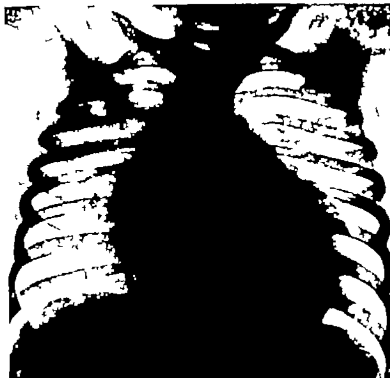


Fig. 13 1.—A large pericardial effusion complicating rheumatic carditis in a child. It was preceded by a pericardial friction rub.

The precordial pulsation, previously tumultuous in patients with rheumatic carditis, becomes less and the heart sounds faint. Radiologically the size of the cardio-pericardial outline differs greatly, depending upon the distensibility of the sac, which varies in different individuals. Severe compression may accompany a not very large shadow and the clinical features are more important than the radiological ones. Large effusions by compressing the left lower lobe bronchus may produce atelectasis of that lobe.

The diagnosis of rheumatic pericardial effusions from other causes depends on the history and the previous presentation of typical rheumatic conditions, signs and symptoms, and a pericardial friction rub which usually precedes the effusion. With absolute rest and administration of salicylates the condition often subsides without the full development of Beck's triad of acute compression, but if this is present and the circulation is embarrassed aspiration of the compressing fluid is essential.

Tuberculous effusions are more insidious in onset and a typical rheumatic story is lacking; an associated or preceding pulmonary tuberculosis may have been diagnosed and

when signs of cardiac compression develop in a patient undergoing sanatorium treatment the diagnosis is readily suspected More commonly the condition develops slowly with malaise, listlessness, dyspnoea and cyanosis following what may have been considered influenza or pneumonia The tuberculous effusions because of their slower development distend the sac more and the radiological outline of the heart may be very large An absolute diagnosis will be made by finding the tubercle bacillus in the aspirated fluid

Treatment of tuberculous effusions. Whether there is associated lung tuberculosis or not the patient must be at complete bed rest The indications for pericardial paracentesis are as in rheumatic effusion but should include the replacement of the fluid removed by a sixth of its volume of air the object of maintaining a pneumo-pericardium is the simple one of keeping the visceral and parietal layers of the sac apart The usefulness of the measure is, however, most doubtful because severe constriction of the heart is found when the pericardial sac has not been obliterated by adhesions If aspiration is employed streptomycin (1 gramme) should be left in the sac at the close

Perhaps the most important thing in the management of the tuberculous pericardial effusion is the need for watchfulness for early signs of the development of cardiac compression and pericardial constriction If the radiograph shows a great increase in the size of the cardiac outline it may be assumed quite wrongly that the condition is one of effusion only, even though the veins in the neck are becoming more obvious and ascites and hepatic enlargement is developing If clinical evidence of true constriction of the heart develops, there should be little anxiety about operating in a subacute phase because true contraction of the visceral pericardium will not commence until healing has partly started Streptomycin seems to be most efficient in preventing any spread of the tuberculous process elsewhere in the body if operation has been carried out The radiograph (Fig 13 2) was from a patient, known to have had a tuberculous effusion for over a year In spite of the shadow and the presence of a pint of fluid in the pericardial sac at operation the patient had all the classical features of constrictive pericarditis and the heart beneath the tuberculous caseous effusion was small and gravely strangled

Purulent effusions

Although Romero (1819) first drained a purulent pericarditis with success early in the nineteenth century, the death rate from the condition is still about 50 per cent and surgical drainage is apparently only rarely performed Truesdale (1933) could collect only 152 examples of this operation in the literature and this survey revealed a death rate of 42 per cent , it may be presumed that many unavailing operations have never been reported In generalized septicaemia, patients may die with this condition as a preterminal complication, the autopsy findings revealing a fibrinous or sero-fibrinous pericarditis without cardiac compressions An important group of patients, however, develop a purulent effusion as a complication of pneumonia or empyema Donaldson (1943) believes that only half the patients with purulent pericarditis are diagnosed in life

Diagnosis. It is unwise to expect that all the physical signs classically associated with the disease will be present Pyrexia, tachycardia and cyanosis are usually associated with dyspnoea , the neck veins may be engorged , enlargement of the cardiac outline may not necessarily be associated with distant cardiac sounds as the fluid may be located chiefly in the posterior pericardial compartment with the apex beat displaced forwards, but radiology will be of great assistance in demonstrating the feebleness of the cardiac movements Pulsus paradoxus may be present

A high pyrexia, often due to the causative septicaemia, is important in association with

signs of acute cardiac compression When the disease develops in the course of a septicaemia or pyaemia or following a major thoracic operation such as pneumonectomy it may be over looked as the toxaemia feeble pulse cyanosis and other features may be ascribed to pleural or pulmonary complications

Treatment Immediate surgical drainage is required as soon as a pericardial para centesis has produced evidence of pyogenic infection Urgent relief by surgical evacuation is essential to relieve the burden of a compressed heart in a highly toxic patient and to prevent the danger of loculation taking place such loculation will be favoured by attempt ing cure by aspiration and the instillation of antibiotic or chemotherapeutic agents





Fig 13 2 Fig 13 3

Fig 13 2 —Radiograph of a man of 30 with tuberculous pericarditis.

T bercle bacilli were discovered in the fluid removed by aspiration. While on strict bed rest and with streptomycin severe symptoms and signs of constrictive pericarditis developed. At operation the heart was extremely small and constricted, the enlarged cardio-pericardial shadow being due to fluid and caseous material in the pericardial sac.

Fig 13 3 —A radiograph of a haemo-pericardium

A tiny fragment of metal is present in the left border of the pericardio-cardiac shadow in the fourth intercostal area A week after entering the patient developed signs of cardiac tamponade with rapid increase in the size of the pericardial outline The pericardium was opened the foreign body removed and a large amount of blood-stained fluid evacuated with complete recovery

Haemo pericardium Apart from rare causes such as rupture of an aneurysm scurvy or malignant tumours gun shot wounds and stab wounds are the exciting agents In warfare the site of entry may be near or in distant areas cardiac tamponade may not necessarily develop rapidly but whether fast or slow continuing bleeding will produce the classical Beck triad and urgent surgical exploration will be needed Foreign bodies impacted in the parietal pericardium or the myocardium may cause a blood-stained effusion tense enough to compress the heart An instance of this is illustrated in Fig 13 3

The technique of pericardial paracentesis This is performed under local anaesthesia with suitable premedication A wide-bore needle is no more dangerous than a narrow one and should be used it should be at least 2 mm in diameter smaller needles become blocked by fibrinous exudate and their use is not uncommonly the cause of error in diagnosis as failure to produce fluid may be taken as an indication that none is in fact present Of

the several possible sites such as the fourth left interspace 1 5 cm from the sternal edge, the fifth space just outside the assessed site of the apex beat (often difficult to determine), posteriorly in the scapular line in the seventh space or to the side of the ensiform cartilage, the last mentioned is the most safe and efficient

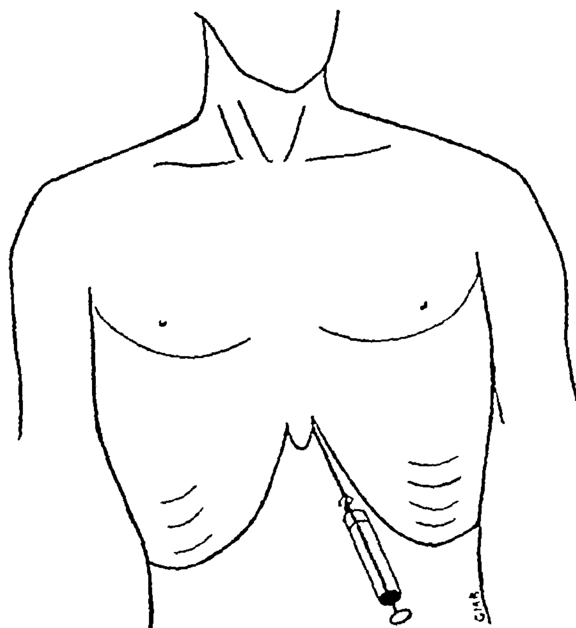


Fig 13 4 —Aspiration of pericardial effusion at the side of the ensiform cartilage

The needle is directed upwards, backwards, and inwards and the depth of penetration is deeper than in the anterior approach through the left fourth or fifth space, but it strikes the area where fluid most readily gravitates, where the potential size of the pericardial sac is the greatest and where there is least danger of injuring a coronary vessel should the heart be inadvertently pierced The needle is inserted as close as possible to the apex of the angle formed by the ensiform cartilage and the cartilaginous costal margin Aspiration alone is indicated in the rheumatic effusions causing compression but in tuberculous pericarditis 1 gramme of streptomycin should be left in the sac after each withdrawal of fluid If pyogenic pus is withdrawn the indication for surgical drainage exists, but penicillin should be instilled as the withdrawn sample will have to be examined bacteriologically before surgical intervention is finally invoked

Drainage of purulent pericardial effusions The variety of approaches that have been used indicate that the problem is not simple but the principle of establishing drainage at the most dependent point (first suggested by Allingham in 1904) appears each year to become more firmly established Donaldson's approach (1943) has the attractiveness of simplicity and directness this approach to the pericardium is through the perichondrium of the seventh left costal cartilage which is resected for two inches immediately adjacent to its junction with the sternum The approach is technically a more simple one than that made in the angle formed by the ziphisternum and the costal margin and there is no danger of opening the peritoneal cavity

The other operations of access through resection of the fifth or sixth left costal margin are too high to allow drainage of the lowest recess of the sac and their use may endanger the pleural cavity This latter risk is even more formidable in a posterior approach in which the pericardium is approached extrapleurally, after resection of the posterior ends of one or more ribs

When the pericardial sac has been opened and most of the pus has drained out, the pericardial sac should be gently irrigated with normal saline and the finger used to explore its posterior recesses to ensure against loculation The maintenance of the drainage opening is not easy , large tubes left in the pericardial sac have the obvious potential risk of damaging the heart wall A large whistled tip catheter should be left with its flange just within the sac and when this site has been judged it should be sutured to the skin the skin and soft tissue should be left widely open and the patient's position changed regularly to a semi-prone or prone one at different intervals throughout the day to encourage drainage Daily saline irrigation is followed by penicillin instillation or other antibiotics appropriate to the organism detected The major post-operative difficulty is to maintain an adequate drainage opening for a sufficient length of time.

Constrictive pericarditis

The surgical relief of the crippling effect upon cardiac output produced by the depos and contraction of fibrous tissue on the visceral and parietal pericardium will be disapp ing if employed too late Delayed excision of the strangling fibrous tissue does not the atrophied muscle fibres of the myocardium to recover rapidly nor permit the dyna of the circulation to be restored adequately Moreover in late cases of constrictive carditis associated with polyserositis the liver may become permanently damaged an relief of ascites may be disappointing

Pathology Healing tuberculous tissue has the greatest power of contraction as in pulmonary disease and although other etiological processes may produce a constr pericarditis tuberculous disease is the basis of the typical picture Rheumatic dis frequently productive of intrapericardial adhesions does not cause true heart constric for vascular rheumatic adhesions do not contract to any great extent nor do they pre the enlargement of the chronic rheumatic heart associated with involvement of the cardium Paul White (1935) thought that if rheumatism could cause Pick s disea did so in only the rarest cases Quite exceptionally a persistent contracting fibrosis fo a suppurative pericarditis or haemo pericardium Blalock and Burwell (1941) rep pericardiectomy in 20 patients in 13 the etiology was tuberculous in 3 it follow previous staphylococcal infection and in 4 the exact cause was not determined

The evidence for a tuberculous etiology depends on clinical observations the histolo appearance of the excised pericardium and the discovery of tubercle bacilli An incre number of patients are seen in whom the progress from tuberculous pericardial eff (tubercle bacilli being recovered from samples obtained at paracentesis) to constri pericarditis can be observed during their sanatoria regime (Fig 13 2 and Fig 13 5) risk of producing dissemination of the disease by operating in a subacute phase is decr by using streptomycin and pericardiectomy is sometimes performed when the disea still proliferative The tissue excised at such operations shows a more characteristic struction than in specimens removed after the tuberculous activity has died down succeeded by a dense fibrosis sufficiently violent to have destroyed the evidence of acteristic tubercles The high incidence of calcification supports a tuberculous etio

A tuberculous serous pericarditis like a pleural effusion may absorb completely or without aspiration but as in the pleura an increase in cellular and protein conte the fluid is followed by a deposit of fibrin on the parietal and visceral pericardium w become organized into hyaline fibrous tissue with all its potentiality for extreme contrac It is the strangling effect of the fibrosis on the visceral pericardium that produces characteristic pathological and clinical effects the heart muscle apart from invasio septa of fibrous tissue remains essentially normal but the constricting process inter especially with the diastole of the ventricles The deposition of fibrous and calcified t does not follow any set formula and in some patients the constriction of the heart is obvious over the left auricle and left ventricle

Calcification is seen in advanced disease along the borders of the heart frequ forming rings around the entrances of the great caval openings fibrous and calc plaques may interfere with the cardiac conducting tissue and this no doubt is the c of such irregularities as auricular fibrillation

The small indistensible heart receives a diminished supply of blood with a conseq reduction in cardiac output there is a steady rise of venous pressure visible and measu in the veins of the neck the liver enlarges and ascites follows The peritoneal flu

a transudate unless there is tuberculous peritonitis as well as pericarditis Pleural effusions, oedema of the legs, and cyanosis are also present in severe degrees of constriction In long-standing ascites the liver, spleen and peritoneum become covered by a dense, white layer of fibrous tissue ("icing-sugar coating")

Diagnosis. Ascites, raised venous pressure and a quiet heart (Beck's triad) indicate clearly the diagnosis in a patient who is also dyspnoeic on exercise, who often looks ill and malnourished, though some appear well while at rest In addition to the peritoneal effusion one or both pleural cavities may be the site of effusion The outstanding feature of ascites may prompt a false diagnosis of hepatic cirrhosis of doubtful etiology, but in my own





(a) (b)

Fig 13 5

(*a*) Radiograph of chest showing bilateral pulmonary tuberculosis and a small heart shadow
The patient had ascites and advanced signs and symptoms of constrictive pericarditis

(*b*) The post-mortem appearances
A small heart with considerable thickening of the visceral and parietal pericardium. The pericardial sac in parts of its diaphragmatic aspect is not completely obliterated.

experience the patients most frequently misdiagnosed are those who show auricular fibrillation with gross peritoneal fluid In the group with ascites and pleural effusion the chest radiograph not infrequently shows evidence of healed or active tuberculosis and the whole picture may be regarded as one of pulmonary and abdominal tuberculosis, as was so in three of my pericardiectomy patients When the diagnosis has been overlooked, the patients have usually been mislabelled as suffering from tuberculous peritonitis, cirrhosis of the liver, valvular heart dyspnoea, and ascites of unknown etiology (Churchill, 1935)

Blalock and Burwell (1941), though stating that the diagnosis can usually be established with confidence, indicate mistakes that have been made and give the following list of possible errors.

Other types of pericardial disease Pericardial fluid, mediastino pericarditis and poly serositis (this last is often associated with true constrictive pericarditis)

Diseases of the heart (a) Tricuspid valve disease (b) diseases accompanied by failure of the right ventricle mitral stenosis cor pulmonale myocardial disease

Extracardiac disease (a) Cirrhosis of the liver (b) mediastinal tumours (c) nutritional oedema (d) multiple thrombosis of veins (e) conditions associated with marked increase in intrathoracic pressure

Once the true nature of the condition has been suspected an accurate diagnosis is made by noting (1) the obvious rise in venous pressure seen especially in the neck veins which show visible pulsation and confirmed by the recording of the actual pressure which may be as high as 30–40 c c of water (2) By the presence of ascites and possibly of pleural effusions (3) The clinical and radiological demonstration of a quietly beating heart The radiological shadow of the cardiac area may be larger than usual because of the mass of pericardial fibrous tissue but screening and the use of the kymograph will indicate the reduction in the heart pulsation The heart sounds are usually faint (4) Calcification of the pericardium when present is conclusive evidence but occasionally the differentiation from calcification in the heart itself (which is not usually associated with constrictive pericarditis) may be required (5) A low systolic blood pressure with a small pulse pressure accompanies a tachycardia which seems to offset the lower cardiac output Pulsus paradoxus is usually but not always detectable and in 20 per cent of the patients auricular fibrillation is present (6) Characteristically the electrocardiograph shows a low voltage and the T waves may be inverted (7) Reduced cardiac output and usually a rise in the pulmonary artery pressures

The aims of surgical treatment The release of the heart from its constricting envelope can only be achieved by pericardiectomy which must expose and free enough of the cardiac muscle to allow satisfactory diastolic filling Unsatisfactory results are largely due to inadequate excision of the fibrous or calcified envelope but a complete excision though theoretically indicated, adds to the operative risk of opening the heart chambers especially the thin walled auricles Opinion is divided as to the need for complete freeing of the areas of entrance of the inferior and superior venae cavae When these are encircled by calcified tissue their surgical liberation is dangerous and most surgeons believe that a wide freeing of the borders of the heart is sufficient this entails a wide decortication of the right and left ventricles and the complete freeing of the inferior border of the heart from the diaphragm The fixation of this area of the heart to the diaphragm leads to limitation of its filling and contraction during inspiration and produces the phenomenon of pulsus paradoxus (Holman, 1949)

Sellors (1946) believes that the surgical object is to allow an increase in diastole and limits his pericardiectomy to the freeing of the right and left ventricle and records good results after this Holman (1949) however favours extensive removal and because of this advocates a wide median trans-sternal approach in preference to a left extrapleural or transpleural exposure Churchill (1949) believes that the chief interference with cardiac function is on the left side and proposes a wide decortication of the left ventricle and the entrance of the pulmonary vein into the left auricle and points out that constriction at this area may simulate advanced mitral stenosis The necessity for a freeing of the left side of the heart is becoming more and more generally accepted In spite of the radiological absence of pulmonary plethora on the radiograph cardiac catheter studies invariably disclose pulmonary hypertension

An experience common enough to most surgeons that a second operation is not

infrequently required for the purpose of further removal of the constricting membrane points to the need for thorough freeing, but all operations must be executed as safely as possible and a too ambitious dissection over the thin-walled auricles may be unjustifiably dangerous It is most unwise to attempt decortication in areas where the operative field is not in good view the temptation to free the right ventricle widely through a left-sided approach once led me into the grave difficulty of having to deal with a tear into the chamber of that ventricle after a badly judged attempt to free an area without a good enough exposure The necessity to improve diastole of the right as well as the left ventricle is not entirely met by the usual left parasternal or transpleural approach, and in the future the extensive median sternotomy approach advocated by Holman may find more supporters Sweet of Boston has increased the exposure by splitting the whole length of the sternum The exposure it gives enables a safer stripping of the thinner right ventricle to be done in the left-sided approach it is easier to free the left ventricle more widely as this area of the heart is thicker in muscle, usually less firmly bound down by fibrous tissue and easier to see

Having employed the sternum splitting approach for a time, I have returned to the left-sided approach as the necessity for clearing the back of the left ventricle has appeared to be more and more advisable

The timing of surgical intervention. The difficulties of this problem include attention to two main factors the inadvisability of operating too early on a febrile, ill patient with active tuberculous disease of the pericardium, and delaying too long a surgical correction of a severe mechanical embarrassment that may progress steadily, not only with further deterioration in the patient, but with the great risk of increasing the surgical difficulties because of the increasing denseness and calcifying nature of the fibrosing process If the patient is seen in the early stage of tuberculous serous pericarditis with commencing signs of cardiac compression, treatment will consist of rigid bed rest, general constitutional management and aspiration of the fluid Streptomycin should be given parenterally combined with para-aminosalicylic acid to decrease the chance of providing a resistant strain Such a patient need not necessarily proceed to constrictive pericarditis and throughout this period the elimination of tissue fluid is encouraged by the use of diuretics such as Mersalyl and by a low sodium diet If the true picture of constriction develops the choice of time for operation will depend on reduction in any existent pyrexia and a drop in the sedimentation rate, ascites and pleural effusion being dealt with by aspiration If the mechanical effects of the constriction steadily increase the operation should not be delayed and the risks of tuberculous infection can be combated by streptomycin therapy, an increasing number of patients with living tubercle bacilli present are being safely piloted through operation

Pre-operative treatment. A period of bed rest in hospital is required Every effort is made to decrease excess tissue fluid by restricting fluid intake and placing the patient on a salt-free diet and by the exhibition of mercurial diuretics fluid in the pleural and peritoneal cavities is thoroughly aspirated Digitalis, which decreases cardiac output, is not prescribed unless the constrictive process is complicated by auricular fibrillation with tachycardia or by myocardial insufficiency (Burwell, 1940) Many of the patients with polyserositis have low protein plasma levels and a high protein diet is indicated

The operation. After basal narcosis, intratracheal anaesthesia is induced ether has advantages over cyclopropane as it lessens the extent of the extrasystoles and of cardiac irregularities, both agents, however, decrease cardiac output Nitrous oxide is contra-

indicated because of the dangers of anoxia To decrease the venous congestion the operating table should be in a partial anti Trendelenburg position

Three surgical approaches are available

(a) *The left extrapleural approach* A large musculo-cutaneous flap is turned laterally after a mid line incision has been made from the second to the sixth left costal cartilage The third fourth and fifth cartilages are divided or resected the left pleura is displaced laterally by blunt dissection after ligation and division of the internal mammary vessels The exposure given by this operation is not very wide

(b) *A left intrapleural approach* The third left intercostal space is widely exposed and opened the third and fourth costal cartilages are divided close to the sternum and a rib spreader introduced the exposure obtained is superior to that of the para-sternal approach and with good anaesthesia and sound post-operative care of any resultant pleural effusion there are no disadvantages in operating across an open pleura

(c) *By median sternotomy* This provides an excellent exposure and the divided sternum heals rapidly A mid line incision starts at the level of the second costal cartilage and reaches to the ensiform cartilage which may be resected The space behind the posterior surface of the lower end of the sternum is easily developed by pledglet and finger dissection and the sternum split by the use of Schumacher s bone cutter or Lebsch s sternum splitting knife up to the level of the second costal cartilage At this level the sternum is bisected laterally at right angles to the longitudinal lower section and a wide exposure is obtained by the use of a strong Tuffier s retractor The pleura on one or both sides may be torn accidentally but with intratracheal anaesthesia this is of little moment and the torn area is temporarily closed by a moist saline pack until it is repaired at the close of the pericardiectomy The closure of this wound is by two wire sutures through drill holes on each side of the line of resection and supplemented by interrupted unabsorbable sutures in the periosteum and pectoralis muscle

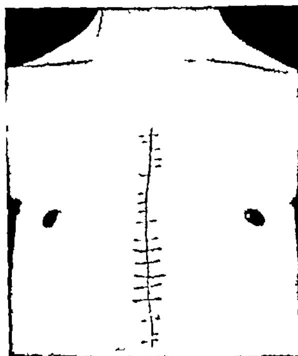


FIG 13 6—The incision after the median trans-sternal approach For constrictive pericarditis

The exposed pericardium presents varying degrees of fixity and thickening The parietal pericardium is cautiously incised and flaps of it well raised before any attempt is made to separate it widely from the visceral or epicardial layer the decortication of which is the important part of the pericardiectomy a plane of cleavage between the two layers of the pericardial sac is usually not difficult to develop the area of adhesion between these being most intimate over the right ventricle The raised flaps of parietal pericardium are held upwards and laterally and segments resected sufficiently to expose the true layer of the constricting fibrous tissue the visceral pericardium this is incised with the greatest deliberation until cardiac muscle is exposed and it is elevated by blunt and sharp dissection At as early a stage as possible the left phrenic nerve is defined and damage to it is avoided Areas of adherent pericardium over the site of the left descending coronary artery are left unresected The left ventricle is decorticated as widely as possible well beyond the line

of the phrenic nerve, before the right ventricle is uncovered to avoid the risk of over-distension of that chamber before the diastolic stretching of the left side has been allowed to deal with the increase of blood flow from the lungs Frequently the area of excision stops at the auriculo-ventricular groove to avoid risk to the coronary artery branches there, and to ensure against tears in the thin auricular walls But the heart must be freed completely from its diaphragmatic area of adhesion and at any areas where pulsation is markedly limited As the decortication proceeds the heart expands visibly into the wound and bulges obviously In the hope of decreasing the frequent extrasystoles and irregularities that accompany the manipulations, applications of 5 per cent procaine have been advised. This is not necessary and such solutions may have local irritating effects If the irregularities become marked and embarrassing to the circulation, periods of rest from actually operative removal of the membrane are more effective than procaine applied locally

At the conclusion of the operation the pericardium is allowed to drain into one or other pleura If a median sternotomy has been used an opening is made deliberately into the left pleural cavity any fluid that exudes can be readily dealt with by pleural aspiration

Post-operative treatment. The need to continue the pre-operative dehydration measures is obvious and for the same reason intravenous fluid should not be given and blood transfusion is contra-indicated unless there has been a serious operative loss which is unusual Oxygen is given for patients with cyanosis and digoxin again is employed only if auricular fibrillation with tachycardia is present

SURGERY OF VALVULAR STENOSIS

The mitral and pulmonary valves have been effectively divided without the production of incompetence (For pulmonary valvulotomy (Brock, 1949) see page 403)

At the time of writing surgery in acquired valvular stenosis is largely confined to the mitral valve since few attempts to relieve aortic stenosis have been made in man since Tuffier (1914) invaginated the aorta above the valve in an effort, apparently successful, to dilate a stenosed aortic valve Bailey (1950) passed a valvulotome through the wall of the left ventricle to incise the stenosis and Brock (1951) attempted it digitally through a left atrial approach Both attempts were unsuccessful and apparently produced regurgitation Bailey and his colleagues are persisting with experimental work and hope to devise a method that will divide the fused valve commissures In their last paper they express hopes that the safest surgical approach will be from above through the right carotid artery and ascending aorta The relief of mitral stenosis, however, has long passed the experimental stage and is an established surgical procedure of undoubted benefit applicable to a large number of patients Plastic operations for the relief of mitral regurgitation are being undertaken but are still experimental (see page 316)

Surgical treatment of mitral stenosis

In Great Britain we are indebted to the work and writings of R C Brock on this subject Using the modern refinements of diagnostic and surgical techniques he has established mitral valvulotomy as a routine operation nearly 25 years after Souttar's solitary and brilliant essay in this field, (1925)

The American work in this field has been thorough, determined and carefully based on methods of experimental surgery and the early attempts by Cutler and Beck (1929) have been succeeded by a mounting number of valvulotomy operations performed by Bailey and his team (1950) and by Harken (1950) Throughout the world the operation

is being practised with increasing frequency and success the indications though widening including about 20–25 per cent of patients with mitral stenosis In selecting patients the knowledge that some with uncomplicated mitral stenosis survive beyond middle life controls or limits enthusiasm for operation so that at present only those who are deteriorating or incapacitated are subjected to surgery it is unwise to operate on advanced cases with poor cardiac muscle and with grossly dilated hearts

Baker Brock and Campbell (1950) in their early work operated on poor risk patients but have greatly extended the field since their paper was published They drew attention to eight pre-operative points of appreciation of the patient s cardiac and general state Generally speaking they regarded the following factors with considerable suspicion (1) active rheumatism in the heart (2) involvement of other valves (3) mitral regurgitation of moderate or severe degree (4) calcification of the mitral valve (no longer regarded as a contra indication) (5) gross pulmonary hypertension (6) auricular fibrillation (7) secondary right-sided heart failure In assessing the eighth factor the state of the myocardium they indicated that an order burdened muscle contracting against the resistance of the stenosed valve may find relief only by the removal of the obstruction and draw the analogy between the bladder and stomach when obstructed In such patients the obstruction should be relieved before decompensation threatens Writing at a time when careful selection was clearly necessary in the formative period of a new branch of cardiac surgery they believed that operation should be delayed in patients in the second decade of life when infection is still likely to be active and they preferred those aged over 25 patients with associated aortic valvular lesions are generally regarded as unsuitable but not excluded if the main cardiac dysfunction is caused by the mitral stenosis

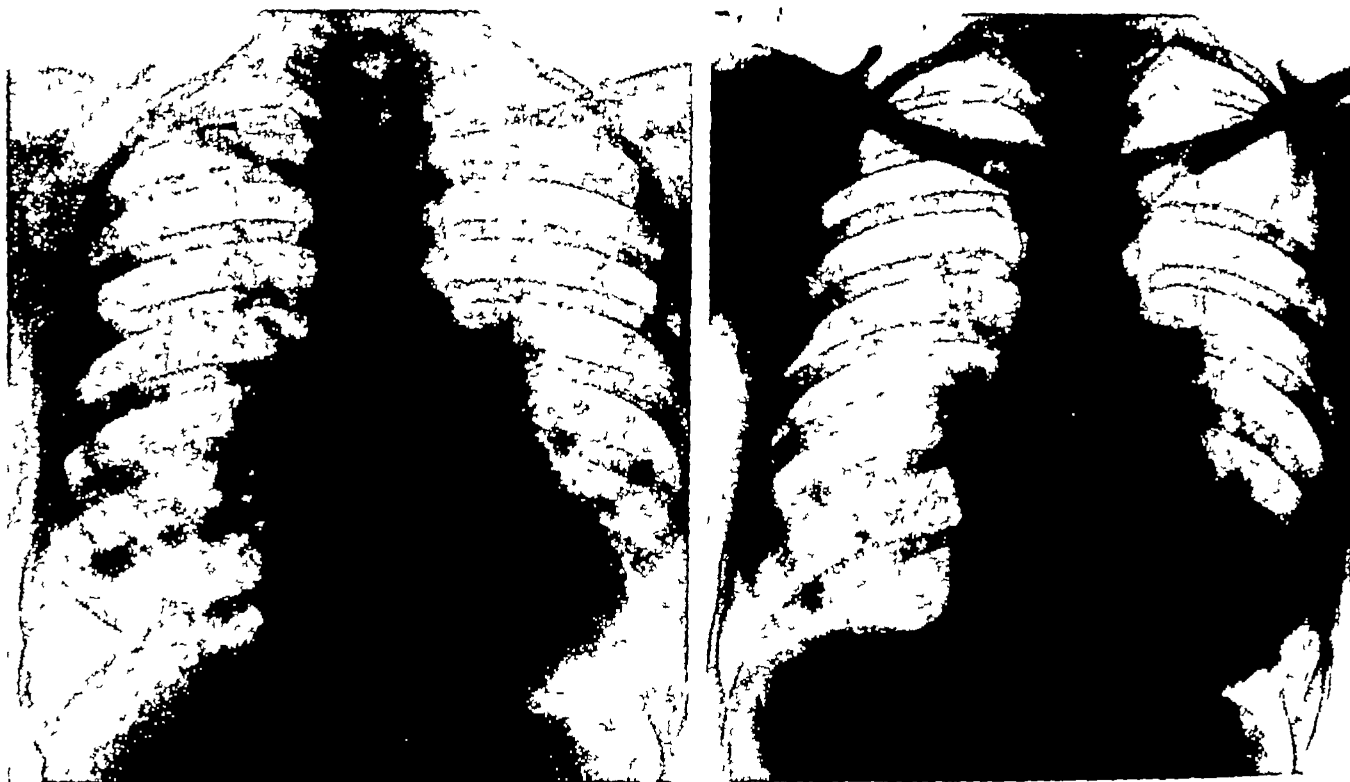
Mitral regurgitation of a degree sufficient to produce a large left ventricle and increased pulsation in a large left auricle are contra indications to valvulotomy In most patients with mitral stenosis there is a slight degree of regurgitation indeed this is felt as a jet proceeding upwards against the finger when this is introduced into the left auricle for the purpose of dividing the valve at its commissure such a division by producing a competent valve prevents this type of regurgitation

Pulmonary hypertensions of all degrees is met with in patients with mitral stenosis although operation may be contra indicated in advanced degrees of hypertension hyper tension is a strong indication for surgery as the lung congestion and the commencing right ventricular hypertrophy will be relieved Many cardiac catheterization studies have now been carried out before valvulotomy and six months after operation, which show beyond doubt that high pulmonary artery pressures have almost invariably dropped very signifi cantly Even the highest degrees of pulmonary hypertension are not contra indications to operation It is interesting and important to note that although the pulmonary arterial pressures drop after satisfactory valvulotomy the pressure rises abnormally quickly on exercise as measured by the catheter

Attempts have been made to relieve advanced pulmonary hypertension by the opera tion of providing a shunt from the pulmonary to the systemic venous system by anastomosis of the azygos vein to the inferior pulmonary vein (Bland and Sweet 1949) This measure has the disadvantage of lowering the cardiac output and although relieving the pressure on the left auricle adds at the same time an immense load to the right auricle which is already suffering from increased pressure as it seeks to overcome the handicap of the associated pulmonary hypertension Ligation of the inferior vena cava below the renal veins (d Allaines *et al* 1949) has been employed but such methods are not widely used

In selecting patients for the operation great attention should be paid to the symptom

of dyspnoea; nocturnal paroxysmal dyspnoea is an urgent indication for operation as these patients have a particular tendency to develop a sudden lung oedema which may be fatal; fortunately dyspnoea, a more favourable symptom, often precedes haemoptysis and when employed as an indication for urgent surgery provides the best results. Haemoptysis is a dangerous signal that severe pulmonary capillary damage has already developed and though by no means a contra-indication to surgery the results of valvulotomy in such people may not be good as the pulmonary hypertension may well have proceeded beyond the possibilities of relief. Although one of the chief aims of surgery is to relieve the pulmonary hypertension, changes following a prolonged rise of pulmonay artery pressure



(a) (b)

Fig. 13.7.—Mitral stenosis.

(a) Radiograph of a woman of 36 with mitral stenosis.
The heart is enlarged, the pulmonary artery is big, the lung fields congested and the aortic shadow small.

(b) After mitral valvulotomy.
The most obvious change is the decrease in pulmonary congestion. The considerable pre-operative dyspnoea in this patient was relieved completely by valvulotomy.

may be irreversible. As a danger signal of sudden rises of pulmonary artery pressure, *paroxysmal dyspnoea and attacks of pulmonary oedema are a valuable pointer to the urgent need for surgical relief of the stenosis.*

The ideal patient for mitral valvulotomy. The rheumatic process should be inactive. It is not easy to assess this accurately but a long history with lack of rheumatic symptoms and a slow blood sedimentation rate may help. Few patients are selected before the age of 20 years because of the danger of persistent smouldering infection in this group. Increasing incapacity from dyspnoea, cardiac asthma, haemoptysis and lung oedema developing in a patient whose regime and medical treatment have been well regulated indicates the need for surgical relief of a mechanical obstruction hindering the outflow of blood from the lungs and so on to the systemic circulation.

The heart should not be grossly enlarged though some distension of the left auricle may be shown on radiological screening the pulmonary artery shadow is accentuated and the aortic one insignificant as seen fluoroscopically and on the radiograph The lung fields show vascular congestion and the degree of pulmonary hypertension can be assessed by cardiac catheterization (see p 359) It is possible that patients with a high degree of pulmonary hypertension will not do very well after operation A pre-systolic mitral murmur with a long rumbling one in diastole is accompanied by accentuation of the second sound in the pulmonary area Although by no means a certain indication of mitral regurgitation a systolic mitral murmur should be regarded with suspicion and requires the most careful cardiological consideration, including the study of cardiac catheterization findings before surgery is contemplated

Some features that are less favourable Auricular fibrillation, calcification of the mitral valve tricuspid regurgitation and moderate or severe right-sided heart failure with a pulmonary artery pressure over 80 mm Hg do not contra indicate surgery but their presence makes the outlook less favourable Many patients with auricular fibrillation and with calcified valves have been operated on with success but both conditions carry a small risk of post-operative embolism and patients with auricular fibrillation on the whole do not do as well as those with normal rhythm Pre-operative systemic embolism is not in itself a contra indication to operation for the clots may have originated from a site that can be cleared of all thrombus at the time of operation It is the stenosis which causes the embolisms and operation may well prevent further catastrophes

Surgeons and cardiologists are now sufficiently pleased with the results of mitral valvulotomy to accept many bad risks and most patients with mitral stenosis who have deteriorated should be assessed with a view to possible surgery

The contra indications to valvulotomy Patients under 20 and those over 50 years are usually excluded from operation but the main contra indication is provided by moderate or severe mitral regurgitation Such patients have a large heart with a loud systolic and a short mitral diastolic murmur and a collapsing pulse with a cardiac output that may be less than 2 5 litres On radiological examination the left ventricle and left auricle are large systolic expansion of the left auricle is by no means a certain indication of regurgitation The exact diagnosis of mitral regurgitation remains difficult in some patients A left ventricular preponderance in the absence of aortic valve disease is a warning against mitral valvulotomy

Coincident involvement of the aortic valve is a contra indication to operation unless the disability of the patient is overwhelmingly due to the mitral stenosis

Severe pulmonary hypertension with gross right ventricular preponderance is to be regarded as an unfavourable feature but is not an absolute contra indication Gross pulmonary hypertension is often reversible according to data based on the pre and post operative study of pulmonary artery pressures recorded through the cardiac catheter

The aim of surgical treatment The morbid anatomical changes consist largely of a lateral and medial fusion of the cusps so that at each end of the normal slit like openings commissures are developed towards the points where they join the mitral ring of muscle If these commissures are split or divided the valvular function may be restored in such a way that regurgitation will not follow and this technical fact disposes of the argument that valvulotomy only converts a mitral stenosis into a mitral regurgitation in fact a successful commissurotomy (a term introduced by Bailey 1950) by re fashioning the valvular action of the previous rigid slit in the stenosed valve decreases the associated regurgitation The commissure may be cut by a valvulotomy knife or torn by the finger

Whichever method is employed the aim is to free the valves at those " commissures " and under no circumstances should the patency of the stenosed valve be increased by incisions across the cusps such a division especially of the medial and larger cusp would inevitably produce regurgitation The division of the commissure by the finger is more popular than by an instrument, though some rigid commissures will not tear evenly by this method and a cutting instrument will be required Once a cut has been made in the commissure the finger can usually enlarge the tear so initiated up to the muscle of the valvular ring Splitting of the commissures is usually far easier when the orifice is small and surrounded by dense fibrous or calcified tissue than in valves that are thin but with tough elastic fibrosis in the edge of the mitral opening. When the whole area including the left ventricular papillary muscles and the mitral ring are the site of a widespread fibrosis the condition may be found at operation not to be amenable to surgical relief, but plastic operations may ultimately be successful (see below)

The operation. Intratracheal ether-oxygen is perhaps the safest anaesthetic. Procaine, both intravenously and locally, may diminish the severe form of cardiac arrhythmias but has the great defect of lowering the systemic blood pressure and is not used by the writer The anterior thoracotomy approach may be employed as in the operation of pulmonary valvulotomy for congenital pulmonic stenosis (see p 403) An excellent exposure is obtained by the classical thoracotomy incision through the bed of the fifth rib with the patient lying on the right side The pericardium is opened widely in front of the phrenic nerve, followed by two transverse incisions to allow a large pericardial flap to be held over to the right

The pulmonary artery presents as a greatly dilated vessel resembling an extra chamber of the heart and its gross size may be a source of difficulty If the auricular appendage is unusually small there may be difficulty in placing a curved clamp across its base

The placing of this clamp is the first manœuvre and it does not interfere with the heart's action Occasionally there are adhesions between the appendage and the pulmonary artery which must be divided before the clamp is placed The handle of the clamp may be to the right or the left if as is usual the first assistant is standing to the right of the operating table it may be easier for him to control it if the handle is to the right, but much depends on the shape of the appendage Two purse-string sutures may be inserted in the wall of the appendage above the clamp in such a way that if necessary they can be drawn up so that the appendix fits snugly round the operator's finger, though they are not essential, in addition two fine stay sutures can be applied to opposite ends of the incision so that the appendage can be lifted up if a tear in it develops, the purse-string can well be omitted The appendage is then opened sufficiently to allow a finger to slide into the auricle as soon as the clamp has been loosened, if this manœuvre is well timed there is no blood loss, if the folds within the appendage are adherent they must be divided and any clot present removed If clot is present and has been removed the clamp should be released to allow a gush of blood to expel any loose portions before the finger is introduced into the valve The finger is advanced into the orifice of the mitral valve, this is nearer and more anteriorly placed than might be expected, in many instances a small jet of blood can be felt issuing upwards and is a guide to the orifice itself The orifice may be so small that only the tip of the finger can be engaged, but as the finger is forced through, first against the anterolateral and then against the posteromedial commissure, the opening soon admits the whole finger into the ventricle The aim, as already stated, is to split the two commissures and not to dilate or rupture the valve itself, the actual division is carried out by rapid movements, care being taken not to obstruct the orifice for more than two or three beats of the

heart at a time as during the actual splitting the blood pressure falls to a dangerously low level The splitting should be carried to the muscle of the mitral ring which is usually felt quite readily It is not always possible to split both commissures

The use of a valvulotome has advocates but Brock although he uses this instrument frequently, prefers the use of the finger which is more precise and under better control than any valvulotome however ingenious it may be If however the finger does not readily

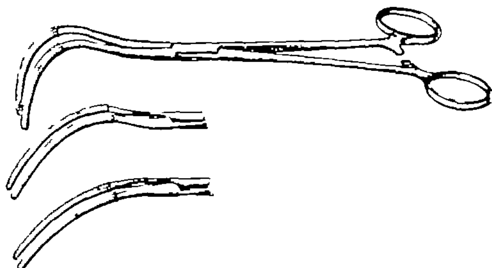


FIG 13 8 (a)—Three types of auricular clamps designed by R C Brock. The clamps are of different sizes and have different curves. (G U Mfg. Co.)

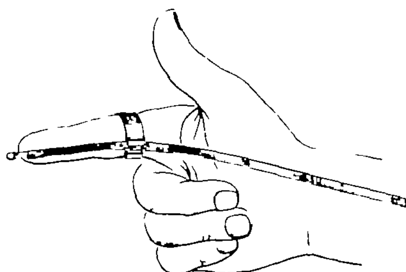


FIG 13 8 (b)—Brock mitral valvulotomy knife and holder (G U Mfg Co)

start a split in the commissure a knife is necessary it can be held in the manner advocated by Bailey two gloves are placed on the right hand and through appropriate cuts in that part of the second or outer glove the knife can be fixed to the palmar surface of the index finger which is once more inserted into the auricle and the tip of the finger guides it into place in the angle of the stenosed valve and the cut is made In my opinion the best valvulotome is the instrument devised by Brock (Fig 13 8 (b)) *but finality has clearly not been* reached in the design of a really efficient instrument

When the valve mobilization has been completed the clamp at the base of the auricular

appendage is quickly re-applied as the finger is withdrawn, part of the clamped-off app age is excised and the opening closed by interrupted silk or thread sutures

The pericardial flap is sutured back in position but large gaps must be left to post-operative effusions to escape into the left pleural cavity

Post-operative complications. In addition to those common to all intratho operations such as post-operative effusion and atelectasis, specific complications suc auricular fibrillation and embolisms may develop Auricular fibrillation is not a co indication to operation if it develops post-operatively it is treated by digitalis if the rate is fast. If the fibrillation persists, the effect of quinidine may be tried

Embolism is an undoubted danger and may be cerebral or to the lower end of the a the femoral vessels or the upper limb channels Constant watch should be kept on al main vessels in the immediate post-operative period as embolectomy has been carried with success in some patients in whom the obstruction has occurred

Mitral regurgitation

The pre-operative assessment of gross mitral incompetence is not always simple loud mitral systolic murmur without a thrill, with diminished accentuation of the ap first sound without the characteristic snap, typically heard in the presence of stenosi suggestive of gross incompetence The suspicion is aggravated if the left ventricl enlarged and the left auricle shows real systolic expansion in the antero-posterior view w the heart is screened radiologically, but mitral stenosis of a pure type may well be ass ated with systolic expansion of the left auricle, especially when seen only in the obli position The certain diagnosis of the state of the mitral valve in some patients can c be detected by the exploring finger of the surgeon

The possibility of correcting mitral regurgitation by surgery remains as a challen At the present moment efforts have been made to relieve regurgitation by the use of ten covered by a vein graft or by the use of a pericardial flap Logan of Edinburgh has p lished a preliminary report on ten patients on whom he has operated on by the meth described briefly below, there have been no deaths and the patients have expressed th belief that they have been helped. He and his medical colleague (Logan and Turner, 19 do not make anything but modest claims

The operation. The heart is exposed as in the operation of mitral valvulotor Usually the mitral valve is explored in the normal manner, if there is gross incompeten quite unsuitable for commissurotomy, a large pericardial flap is fashioned from the side after the phrenic nerve has been dissected clear and preserved, the flap is usua hinged on the area near the pulmonary veins it is essential to have a good length of pe cardial tissue which is then sutured to the eye of a 7-inch silver probe This probe is th passed through the left ventricular wall in an area free from vessels its position is judg by a finger in the mitral opening and the probe guided just below the anterior commiss through the chamber of the ventricle to emerge through the posterior ventricular wall ju below the posterior commissure Care is taken to select a point of emergence free fr vessels The probe is then bent to enable the graft to be pulled through without disturbi the position of the heart too much the degree of tautness of the pericardial band as passes below the incompetent valve is estimated by the finger in the auricle, it should so placed that in systole it bellies up into the incompetent ring, but can float away in diast so that blood can flow from the auricle into the ventricle When this disposition has be decided upon the pericardial flap is sutured to the posterior wall of the left ventricle T auricular incision is dealt with as described in the operation of valvulotomy.

CARDIAC INJURIES AND WOUNDS

Perforating penetrating and crush injuries of the heart though rare in civilian practice require consideration In explanation it must be stated that a penetrating wound differs from a perforating one in that in the former a foreign body lodges in the pericardium the heart muscle or within the chambers of the heart A number of cardiac wounds survive the initial injury Wood and Nicholson (1945) studied 25 survivors at a base hospital out of 1 040 consecutive chest wounds and d Abreu Litchfield and Hodson had 10 in 1 000 patients under similar conditions Harken (1946) not only indicates that many soldiers wounded by missiles lodging in or near the heart and great vessels survive but in an astonishing series of 134 patients operated on for the removal of such missiles there were no deaths of these 134 56 foreign bodies were removed from within or on the heart of which 13 were taken out of a chamber of the heart itself

Clinical features of wounds of the pericardium and heart

In those who survive the initial gun-shot or stab wound the subsequent course may be dramatic or quite uneventful it was not unusual in the last war to see symptomless well soldiers with intracardiac foreign bodies present who at no time after the initial wounding presented symptoms or signs that caused the least degree of anxiety In others however the effects of cardiac tamponade were obvious at an early stage Tamponade depends on two factors firstly with small wounds of the ventricles especially blood leaks out during diastole with a steady increase in intrapericardial pressure secondly the heart may be embarrassed by a pericardial effusion which forms in response to the irritating effect of blood in the sac and occasionally to the presence of a foreign body With increasing intrapericardial pressure pallor cyanosis and a fall in the systemic blood pressure are associated with a feeble pulse and cold limbs The heart beat on palpation is quiet Unconsciousness may result from cerebral anoxaemia The neck veins show a raised pressure but are not conspicuously obvious nor do they pulsate in the early stages as they have not had time to enlarge as in heart failure or constrictive pericarditis the lower blood pressure and reduced cardiac output place the coronary blood supply to the heart itself in danger

The radiological appearances may show an enlarged cardiac shadow but this is not so obvious as in more slowly enlarging pericardial effusions which have time to distend the rigid sac

Treatment This is surgical paracentesis may be required urgently to save life but if possible it should be carried out in the theatre as the release of pressure may encourage rapid bleeding

The pericardial sac is explored through the wound track if this is near to the heart or by a more formal approach The exposure should be wide enough to allow a hand to be passed freely into the pericardial sac beneath the apex of the heart

When the tense pericardial sac has been opened bloodstained fluid and clot may be rapidly extruded to be followed by true cardiac bleeding if the wound is in the ventricular wall the bleeding can be arrested by finger pressure as readily as in a direct operation such as Brock s pulmonary valvulotomy Sutures are passed through the heart muscle beneath the finger and then tied In the rare instance of a wound in one of the auricles finger pressure is not effective and the wall of the auricle must be seized in a clamp underneath which mattress sutures are placed

At the close of the operation the pericardium should be loosely sutured leaving adequate

gaps to allow post-operative effusions to flow into the pleural cavity where they are drained by a water-sealed tube or removed by aspiration

Removal of foreign bodies

Many patients have survived the first and second Great World Wars with metallic bodies embedded in the heart and apart from their removal in the early stage of treatment most surgeons would be loth to advise surgery removal Complications, however, do follow, especially if the metal is in or near the pericardial sac Recurrent bouts of pericarditis with fever, pain and malaise and evidence of effusion are indications for removal which in this site is neither dangerous nor difficult Foreign bodies may migrate, either from the heart itself or from the great vessels Such migration may be the source of great puzzlement unless the phenomenon is remembered * A full account has been given by Barrett (1950), who also describes migratory foreign bodies that have entered the circulation by other than cardiac routes and lists an astonishing variety of material that has circulated He indicates that a foreign body lodged in the cardio-vascular system is always a potential danger to life Those that lodge in the pulmonary vessels or systemic vessels should be removed Cardiac foreign bodies are clearly more dangerous when lodged within the heart chambers and provide a special difficulty to the surgeon he should probably remove them If any surgeon embarks on these operations the writings of Harken (1946) are available for study

Clinical features and treatment of contusions of the heart

Severe contusions of the heart may follow crushing injuries that leave the chest cage intact The characteristic cause is the impact of the steering wheel on the lower sternum in a head-on car collision accident, though this is not a common accident in Britain because of the type of car construction The severe effects of such a contusion may not be obvious for some days, though occasionally death follows instantly from violent rupture of the heart or aorta or ventricular fibrillation Quite exceptionally a haemo-pericardium may follow

In the more usual train of events cardiac bruising may be followed by complaints of weakness and easy fatigue some days or weeks after the accident , in the elderly subjects symptoms of coronary thrombosis may supervene If arterial damage has followed this may lead to infarction and a later cardiac aneurysm Because of these possible disagreeable sequels suspected cardiac contusion should be treated by bed rest for some six weeks with a carefully supervised convalescence

CARDIAC ISCHAEMIA

The surgical treatment of angina pectoris of the recurrent disabling type has involved attempts to relieve pain and efforts to revascularize the ischaemic muscle The disappointing results should not preclude surgery in all instances and too many patients are allowed to suffer intolerable pain that can be relieved by sympathetic denervations, even if the ultimate prognosis with regard to survival remains unaltered While many efforts are being made to improve or devise the methods that bring an actual increase of blood supply to the

* In the first instance I saw I had opened the right chest for the removal of a foreign body in the right lung At the exploration no trace of this fragment could be felt a portable radiograph taken in the theatre showed the metal to have migrated from the right pulmonary artery to the left

cardiac muscle the chief indication for surgery at the moment of writing is the relief of severe pain by neurectomy

Sympathectomy

The afferent sympathetic nerve fibres from the heart pass chiefly through the stellate ganglion and the upper four thoracic ganglia on each side to traverse the white rami communicates before reaching the spinal cord through the posterior nerve roots The most reliable operation would seem to be a posterior rhizotomy on both sets of upper five thoracic nerve roots but this is a more severe operation than cervico thoracic sympathectomy The injection of alcohol by means of a paravertebral block is haphazard however careful the technique and is by no means without dangers because of the spread of the alcohol into adjacent tissues the mortality rate has been higher than that after deliberate cervico-thoracic ganglionectomy If patients with hypertension submitted to thoraco lumbar sympathectomy have associated anginal attacks the upper thoracic chain including the stellate ganglion should be removed.

Indications for sympathectomy No patient should be considered for operation until an adequate period of medical conservative treatment of which perhaps the most important feature is adequate bed rest after the most recent infarction has failed to relieve severe pain The arguments that abolition of the severe pain removes a danger warning from the patient is untrue because the most successful sympathectomy does not entirely remove the sense of substernal oppression (Lindgren 1950)

The operation This is best carried out under general anaesthesia to decrease the possibility of angina during the procedure The ganglia to be removed can be exposed through an anterior supraclavicular incision or through a posterior thoracic extrapleural route The chief advantage of the anterior route is that cardiac patients are alleged to withstand surgery better if in the supine position If the posterior approach is employed a satisfactory operation can be achieved after sub-periosteal resection of the posterior third of the fourth rib the lung being displaced anteriorly and downwards by the technique used for extrapleural artificial pneumothorax This approach has considerable advantages over multiple resections of the deeply placed posterior ends of two or three ribs as commonly employed for cervico-dorsal sympathectomy a transpleural approach adds an unjustified burden to a patient with a severely damaged heart muscle The stellate and upper three dorsal ganglia are resected the left side being done first

Revascularization operations

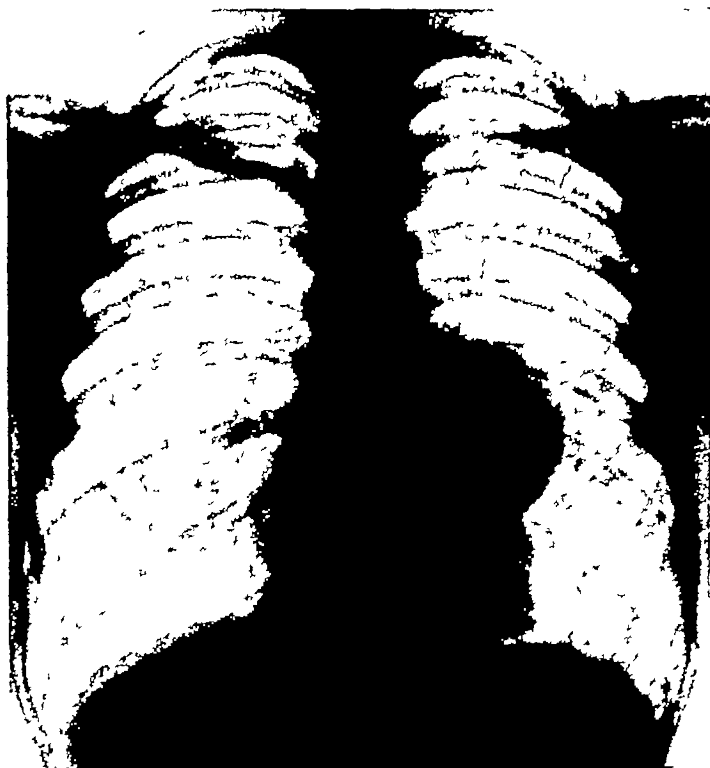
The principles underlying the operations of Beck (1935) who applied pedicled muscle or lung grafts and of O Shaughnessy (1936) who employed omentum brought up through an incision in the diaphragm are good but the evidence that a really satisfactory increase in blood flow is achieved is weak these operations do not have a wide use though Mason (1951) has had encouragement from the results in some grossly incapacitated patients of whom 30 were operated upon with the employment of omentum as the graft

More direct measures have been employed Fauteux (1941 1946) has ligated the coronary sinus and performed a neurectomy of the sympathetic fibres around the coronary arteries Recently Beck (1948) has been anastomosing branches of the aorta to the coronary vein to produce an increased retrograde blood flow through the vessel

TUMOURS AND CYSTS OF THE HEART AND PERICARDIUM

Secondary tumours are much commoner than primary ones The pericardium may be invaded by bronchial carcinoma with the production in the late stages of a blood-stained pericardial effusion , portions of secondarily invaded pericardium are frequently removed with the lung in Allison's extra-pericardial dissection pneumonectomy for bronchial cancer

Primary tumours are rare rhabdomyoma and myxoma are occasionally encountered in adults, teratoid tumours and foregut reduplications affecting the pericardium being seen occasionally (Fig 13 9) Such a cyst successfully removed from within the pericardium in a man of 20 is illustrated in Fig 13 9 The myxomatous tumour may be pedunculated



(a)



(b)

FIG 13 9

(a) Radiograph of the chest of a man of 20 who complained of pain in the left chest

(b) Photograph of intrapericardial cyst removed from this patient

The cyst, which had the macroscopic and microscopic appearance of a bronchial cyst, received a blood supply from the left pulmonary artery (intrapericardial portion) and was connected by a bronchial tube with the tracheal bifurcation

and when sited in the left auricle may imitate the symptoms and signs of a pedunculated ball thrombus, sudden systemic anaemia may follow if the mitral valve is obstructed (Woodhead, 1933) , this may cause sudden loss of consciousness. A full clinical and pathological description of myxoma of the left auricle, of which 77 have been described in the literature, has been given by McAllen (1950) If such a state could be diagnosed accurately in life surgical removal might be possible but few tumours have been removed from the heart Beck has successfully removed a benign tumour of the left ventricle which had a calcified shell and contained frothy-like material rich in fat pericardial cysts have been excised and these have been associated with pericardial defects (Sellors) Fig 13·10 shows a " tumour " of the heart in a woman of 50 , at operation a hydatid cyst was removed (d'Abreu, 1950)

ANEURYSMS OF THE GREAT VESSELS

In spite of continuing efforts to cure aneurysms of the great vessels by surgery interest centres chiefly round their differential diagnosis from mediastinal and bronchial tumours Although there has been a rapid decrease in the number seen annually because of satisfactory treatment of syphilis in the early stages 1 500 patients die each year of the condition (Colt 1948) Aneurysms of syphilitic origin affect males far more commonly than females are usually diagnosed between the ages of 40 and 60 and do not arise in congenital disease 70–80 per cent of the patients have a positive Wasserman reaction

Of the two types fusiform or saccular the latter represents the true aneurysm as the other is a stage of enlargement in a syphilitic aorta the latter carries incidentally a



Fig 13 10



Fig 13 11

Fig 13 10 —Teratoid tumour of the pericardium. A new-born infant. (*Brit J Surg*)

Fig 13 11 —Radiograph of the chest of a woman with a hydatid cyst in the wall of the left ventricle This cyst [illegible] removed. (*Brit J Surg*)

better prognosis though this depends usually on the amount of aortic regurgitation that accompanies it

Aneurysms are commonest in the ascending aorta and the arch both may simulate inoperable bronchial carcinoma though this is far more likely with the arch lesions The aneurysm of the ascending aorta may be large enough to compress the superior vena cava leading to distension of the veins of the head and neck, as in superior vena cava obstruction resulting from a bronchial carcinoma that has spread to the mediastinum the detection of a systolic murmur associated with a thrill and the positive Wasserman reaction will help in the diagnosis On radiological screening pulsation in the aneurysm is more likely to be forceful expansile and definite here than in saccular aneurysms of the arch

Aneurysm of the arch produces important signs and symptoms because of pressure on the left bronchus the left recurrent laryngeal nerve and the oesophagus involvement of the sympathetic nerve chain may give a Horner's syndrome Such pressure signs and symptoms are often present in bronchial carcinoma that has invaded or compressed the

ructures mentioned and care in the differential diagnosis is necessary, quite a number these patients are referred to thoracic surgical clinics as bronchial neoplasms because of e collapse of the left lung and the hoarse voice It is always important to remember that

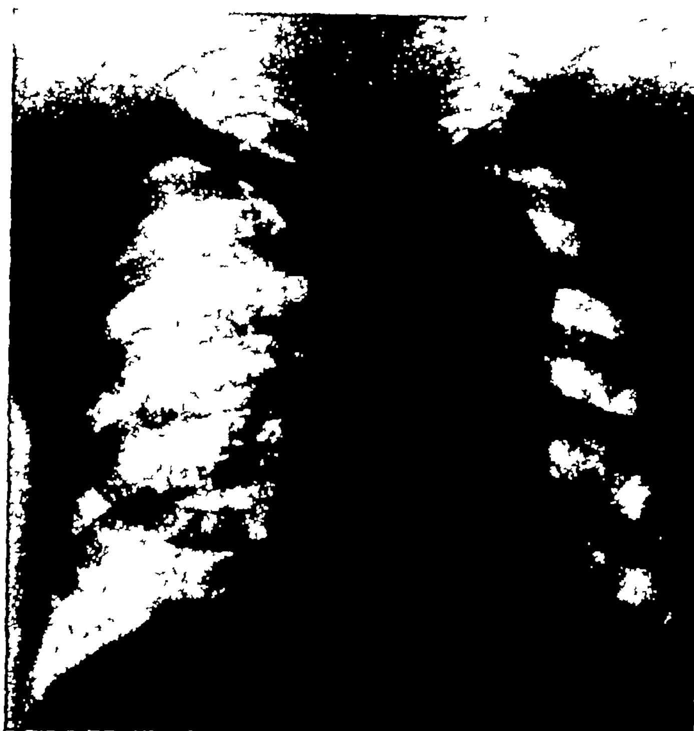


FIG 13 12 —Radiograph of the chest of a man of 44
He complained of pain in the chest and persistent cough, and was referred as a carcinoma of the bronchus on screening there was no insile pulsation seen The Wasserman reaction was negative
At thoracotomy this was a saccular aneurysm of the aorta

iny saccular aneurysms on radiological screening do not show a characteristic expansile lsation nor can reliance be placed on the expectancy that all aneurysms of the arch e the signs of the tracheal tug Angiocardiography is of value in the differential diagnosis thoracic aneurysm (p 344)

rgical treatment of aneurysm

Colt (1948) since 1903 has been the leading enthusiast for the operation of "wiring" eurysms in this country and has obtained some good results, but the method is not wide use though a recent report from Mason's clinic (Borrie and Griffin, 1950) has tored interest in the method Colt's method is clearly applicable to the saccular pe only

The attempt to produce a marked fibrous tissue reaction around an aneurysm by apping it in polythene cellophane has been made by Poppe (1948) and is now probably re widely used than the various wiring methods Abbot (1949) has reported his early perience in the use of polythene cellophane wrapping in 32 patients

Ligature and resection in the treatment of intrathoracic aneurysm At the time of writing racic and abdominal aneurysms both of the saccular and fusiform types are being successfully excised, followed by reconstructive suture and by the use of stored human aortic afts Blalock and Bahnson of the Johns Hopkins Hospital and Brock of Guy's Hospital ve satisfactorily performed spectacular operations of this type and their accounts may published shortly and will be awaited with great interest Alexander (1944) successfully cised an aneurysm of the thoracic aorta which was associated with a coarctation of the

aorta and performed an end to-end reconstruction of the aorta Monod (1950) excised an aneurysm of the aortic arch followed by suture of the diverticulous opening from the aorta

Ligation of the innominate and subclavian arteries Persistent attempts to treat aneurysms of the innominate artery by ligatures placed proximally and distally (on the right carotid and right subclavian arteries) or a combination of both (Lindskog 1946) have provided some notable successes and a full account is given by Gordon Taylor (1950) who has ligated this vessel on seven occasions, though all the patients were not suffering from aneurysm Access to the commencement of the artery is readily obtained by the use of the usual right posterolateral thoracotomy the difficulties of the operation depend entirely on the extent of the aneurysm which may involve its aortic origin.

If either subclavian artery is involved in aneurysm an intrathoracic approach for ligation provides an access far superior to any hazardous attempts from a completely extrathoracic operation alternatively the cervico thoracic approach (p 80) may be applicable

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CONGENITAL HEART DISEASE

INTRODUCTION

These defects produce two different groups of patients, those with cyanosis (the cyanotic group) and those without cyanosis (the acyanotic group) If there is an opening between both sides of the heart cyanosis may develop in the second category if the shunt becomes reversed In both groups there are examples of pulmonary plethora and pulmonary ischaemia In many of the patients there are anatomical defects that can be corrected, or in whom physiological handicaps can be overcome The availability of surgical treatment and the establishment of the exact nature of the deformities by clinical and radiological methods, often supplemented by cardiac catheterization and angiocardiography, means that congenital disease is no longer an academic problem of cardio-vascular pathology Maude Abbott (1928) and Brown (1939 and 1950) have provided admirable accounts of the anatomical and pathological pictures Taussig (1947), by modern clinical, radiological and physiological methods, showed that an accurate diagnosis of the extent, site and nature of the congenital defects is possible in most instances and a correct estimate of the frequency of the lesions obtained. Since then a vast literature on the subject has developed

Incidence of congenital cardiac lesions

Exact figures are obscure, most of the figures available being taken from selected material as the patients tend to gravitate to centres where full investigational and surgical facilities are available or a particular type of operation is in use The material seen varies from hospital to hospital if special facilities are available as at a children's hospital, more infants and young children will be seen than at general and heart hospitals which deal largely with the older age group One thing common to all clinic series is that the incidence as disclosed by investigations of the living subject bears no relation to those published on the evidence of the post-mortem room, and that in Birmingham (Parsons, 1951) and Toronto (Keith, 1950) congenital heart disease is far commoner than rheumatic heart disease in children up to fifteen years of age

Paul Wood (1950) in a series of congenital heart lesions proved by the highest criteria of modern investigations found the incidence as follows

	Cases	Percentage
Acyanotic group		
Atrial septal defect	35	17 5
Patent ductus arteriosus	29	14 5
Ventricular septal defect (excluding 4 with pulmonary stenosis)	24	12
Simple pulmonary stenosis (4 with ventricular septal defect)	23	11 5
Coarctation of the aorta	16	8
Aortic or subaortic stenosis	6	3
Cyanotic group		
Fallot's tetralogy (3 with pulmonary atresia)	36	18
Tricuspid atresia	6	3
Pulmonary stenosis (with reversed interatrial shunt)	5	2 5
Eisenmenger's complex	2	1
Transposition of the great vessels	2	1
Others	16	8

The figures in Wood's scrupulously investigated series differ somewhat from those of Clifford Parsons (1951) working at the Congenital Cardiac Disease Clinic at the Children's Hospital Birmingham perhaps notably in the case of transposition of the great vessels at a children's hospital it is clear that more of these will be seen than at a heart hospital as many infants die in the early months

At the Children's Hospital 430 (all under the age of 14) examples of congenital heart disease have been seen in five years the material is partly selected because patients with lesions considered amenable to surgery are probably referred more often than those as yet not correctable by or indicated for operation Nevertheless the gross figures provide a guide to the type of patient seen

CONGENITAL HEART DISEASE CLINIC

The Children's Hospital Birmingham

Acyanotic group	
Patent ductus arteriosus (proved)	78
Patent ductus arteriosus (probable)	10
Atrial septal defect (proved)	7
Atrial septal defect (probable)	35
Ventricular septal defect (proved)	12
Ventricular septal defect (probable)	60
Pulmonary stenosis (proved)	3
Pulmonary stenosis (probable)	8
Coarctation of the aorta	19
Abnormal aortic arch	6
Aortic stenosis	1
Atrio-ventricularis communis	4
Miscellaneous	14
Not yet diagnosed	34
	297
Cyanotic group	
Tetralogy of Fallot (proved)	48
Tetralogy of Fallot (probable)	8
Transposition of the great vessels (proved)	25
Transposition of the great vessels (probable)	4
Tricuspid atresia	16
Rotation dextrocardia	6
Eisenmenger complex	8
Truncus arteriosus	3
Single ventricle	1
Cor biloculare	3
Not yet diagnosed	11
	133

In the tables above the word probable indicates that the patient's diagnosis has not been confirmed by operation autopsy angiocardiography or cardiac catheterization

These types of classification admittedly incomplete * for they omit reference to some rare lesions indicate the wide field open to surgery in treatment Patency of the ductus

* Paul Wood in his paper concludes with a suggested new classification of congenital heart disease which is highly comprehensive and should be consulted

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arteriosus, the commonest of all acyanotic lesions, is usually treated by surgical obliteration and coarctation of the aorta sometimes by excision of the stenosed segment and end to end aortic anastomosis even the septal and ventricular defects have been submitted to surgical occlusion (Gordon Murray, 1948) although these interventions have not gained an established place in surgery as yet Because the prognosis in patients with pure pulmonic stenosis is bad many operations have now been done for the relief of this by Brock's valvulotomy operation Congenital abnormalities of the aorta (double aorta) when producing dysphagia and dyspnoea with stridor can be corrected surgically (Gross 1946) In the cyanotic group many patients with Fallot's tetralogy andtricuspid atresia are subjected to surgery (Blalock, 1944) and Brock (1950) has provided techniques for the surgical relief of pulmonary stenosis by direct pulmonary valvulotomy or resection of the walls of an obstructing infundibulum The successful surgery of transposition of the great vessels remains one of the most perplexing problems to the thoracic surgeon in spite of Blalock's (1948) brilliant efforts in this particularly difficult field

Conversion of some acyanotic lesions into cyanosis

The causation of cyanosis in the true cyanotic group is central in origin, usually being due to a right-to-left shunt across a septal defect in the presence of hypertrophy of the right ventricle contracting against obstruction of the pulmonary arterial outflow due to infundibular or valvular stenosis or hypoplasia or atresia of the pulmonary artery In the Eisenmenger complex the heart has all the defects seen in the tetralogy of Fallot save the element of pulmonic stenosis and the obstruction may be in the lung parenchyma or the pulmonary vascular bed, causing a late cyanosis following reversal of the shunt

In patients with lesions originally acyanotic, blueness may develop either peripherally or centrally Reversal of the shunt through a septal defect, either atrial or ventricular, due to increasing pulmonary hypertension associated with right ventricular hypertrophy may develop later and accounts for cyanosis ensuing in the 'teens or the twenties The cyanosis may be peripheral as a result of the decrease in cardiac output when the left ventricle begins to fail as in a patient with a patent ductus arteriosus * The later development of cyanosis in patients with pure pulmonary stenosis is explicable on the grounds of the right-sided heart failure, venous blood being forced through the foramen ovale Brock and Campbell have pointed out the extreme dangers under which such patients live and they have a high incidence of sudden death Because of this, patients with pure pulmonic stenosis or associated with an interauricular septal defect are being increasingly submitted to Brock's operation of pulmonary valvulotomy

These defects may be severe enough to cause death at birth or soon after but even in the grossest deformities the physiological and anatomical adaptation may be so flexible that life is possible in spite of apparently hopeless mechanical defects Almost without exception, as life progresses, the burden on either the right or left heart becomes greater and these patients have the added risk of developing bacterial endocarditis The polycythaemia of the " blue babies " is an excellent example of a physiological adaptation while the general tendency for the children to be undersized is in itself a mechanism that eases the heart's burden.

There is no great evidence of a familial incidence though examples have been met of more than one member of a single family being affected arrest of embryological develop-

* Professor Melville Arnott and Dr Donald have shown me two cyanosed adult patients with patent ductus arteriosus in whom catheterization studies showed the pulmonary artery pressure to be as high or higher than the systemic equivalent

ment before the eighth week or the development of defects later (foetal endocarditis) the result of maternal infection may be due to ante-natal influences rather than to genetic reasons. This is supported by the not infrequent coincidence of abnormalities such as mongolism, cleft palate and arachnodactyly, though in our series at the Birmingham Children's Hospital this has been unusual.

Pulmonary circulation in congenital heart disease

Even with the grossest defects this circulation may be maintained. In the common lesion of patent ductus arteriosus the pulmonary blood flow is increased as blood pours into the lungs under the impact of the greater aortic pressure and thus in itself may later produce the effects of pulmonary hypertension and occasionally does so at a very early age (see Fig. 16.5). But in the cyanotic group, in addition to the actual defects in the chambers of the heart, there is in 50 per cent or over of the patients an obstruction to the pulmonary blood flow, the result of atresia or stenosis of the artery or of its valves or infundibulum. If the stenosis is complete or the pulmonary arteries are absent, life can only be maintained by persistency of the ductus arteriosus or the development of anastomotic collateral vessels in the mediastinum, pleura and lungs, hypertrophied bronchial vessels joining the systemic and pulmonary circulations.

The obstruction to the flow of blood into the lungs in the type of patient mentioned above will lead to dilatation of the right heart and a fall in the output of the left ventricle and to a lowered aortic pressure. These changes are represented by a right axis deviation in the electrocardiograph and can be demonstrated by cardiac catheterization and estimations of pressure and oxygen contents. Diminished blood flow to the lungs is evident not only in Fallot's tetralogy but in tricuspid atresia, persistent truncus arteriosus and pulmonary stenosis and atresia.

The pulmonary artery pressure and blood flow is increased in patent ductus arteriosus, ventricular and atrial septal defects, anomalous pulmonary veins draining into the right side of the heart, Eisenmenger's complex and in transposition of the great vessels.

Investigation of congenital heart disease

Helen Taussig indicated the high degree of clinical accuracy obtainable by clinical and radiological examinations alone and how this could be correlated with the pathological anatomy obtained as the result of years of post mortem study. The exact nature of the defects and their physiological and pathological effects can be accurately diagnosed if the investigations include cardiac catheterization and angiocardiography, and Wood (1950) believes that a 90 per cent accuracy is obtainable in the living patient.

History and clinical examination. There is clearly no need to stress the value of a complete history; too much has been said about the presence or absence of "blueness" and too little about the functional capabilities of the patients. Dyspnoea and the exertional incapacity of the patient are not always easy to assess; when severe in blue babies and associated with a history of squatting, a tetralogy of Fallot is often present. The onset of cyanosis and dyspnoea should be discovered from the history if possible; many of those in the Fallot group are not cyanosed in the early months of life while a really late development of blueness is seen in the isolated pulmonic stenosis with an atrial defect or in septal defects when the shunt is reversed, which may not occur till the late twenties or thirties. The children with tetralogy of Fallot usually squat when tired, but this is not absolutely pathognomonic. Clubbing of the toes and fingers are important signs indicating a lesion

causing central cyanosis supported by the high degrees of polycythaemia often met with in many of the cyanotic patients

The routine clinical examination, combined with radiology, will enable an exact diagnosis to be made in many conditions without recourse to more complicated investigations and this is especially so in the acyanotic group of patients where patency of the ductus arteriosus and the presence of coarctation of the aorta are usually easy to detect

The careful noting of thrills, murmurs and the character of the second sound in the pulmonary area provides invaluable information and this has been well stressed by Wood (1950); especially important is the accentuation of the second element of the usually split second heart sound in pulmonary hypertension whereas in the pulmonic stenosis of Fallot's tetralogy it is single, clear and loud as the only sound heard is the aortic one The electrocardiogram studies are specially valuable in indicating whether one or other ventricle is predominant

The slender description given here of clinical assessment in comparison with the fuller accounts given in the chapters on angiocardiography and cardiac catheterization is in no way an attempt to minimize the value of clinical methods, but justice to this aspect of the subject is impossible in a surgical work

The important help provided by cardiac catheterization and angiocardiography requires a fuller description because of the more recent advent of this scientific and accurate help

The following sections on angiocardiography and cardiac catheterization are applicable of course to acquired forms of heart diseases as well as to congenital deformities

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CHAPTER 14

ANGIOCARDIOGRAPHY

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Much has been written about angiocardiography since the papers of Castellanos (1937) and of Robb and Steinberg (1938) The value of the method in the radiographic demonstration of the cardio-vascular structures and circulatory route is now well established This value lies not only in diagnosis but also in the provision of anatomical information to aid the planning of surgical treatment

The essential features of the investigation are two fold Firstly an intravenous injection of contrast medium rapid enough to provide a single bolus which outlines in turn each part of the heart and the great vessels if the injection is slow the contrast medium will be insufficiently concentrated to outline clearly the individual structures while the sequence in which the chambers and vessels fill will not be distinguishable The second essential is a rapid series of radiographs showing the progress of this opaque bolus The normal flow from vena cava to aorta is complete within ten seconds but in abnormal circulations the time may be very much less Thus many pictures must be obtained in a few seconds if the circulatory route is to be demonstrated.

Rapid serial radiography

A variety of methods has been used

1 *Direct radiography* (*a*) With manual change of cassettes (*b*) with mechanical change of cassettes (*c*) without cassettes (using roll film in a special magazine)

2 *Indirect radiography* Photography of the image on the fluorescent screen

The indirect methods give inferior picture quality as there is inevitable loss of definition although the small size of the resultant films simplifies comparison of a long series on the viewing box or by cinematographic projection Exposure times are often long (0 1 to 0·4 sec) The amount of radiation necessary is greater than with direct radiography even with the best lens system obtainable it is at least 8 times as much Since many films are required this is an important consideration the tube must not be overloaded nor the patient and staff over irradiated

For direct radiography apparatus has been designed to move cassettes mechanically into position Lind (1040) and Fredzill (1950) take sixty pictures in five seconds with a machine in which a rotating arm strikes special cassettes off a spring raised pile the instant of each exposure being recorded on a simultaneous electrocardiogram But most mechanical apparatus is designed to work at not faster than one exposure per second thus it would appear to offer no essential advantage over manual change devices and to be inferior to some of these in compactness and rate of operation

Direct radiography with manual change of cassettes uses the minimum of special apparatus One operator with a simple polygraph and a foot-switch to control exposures can take four pictures on the four corners of a 17 × 14 inch film in four to six seconds Two technicians one to feed cassettes into a tunnel under the patient and another to remove them can expose any number of films at rates of up to one a second

Such simple methods as these can give very adequate results, although an occasional picture may be blurred by exposure before the cassette is quite stationary, but the risk of over-exposure to X-rays to which the operators are subjected if many examinations are undertaken must be considered However, simple pieces of apparatus, easily made in the hospital workshop, can overcome these difficulties Devices incorporating a stop-mechanism that ensures the cassettes are really stationary when exposed have obvious advantages A modified form of the conveniently compact manual-change apparatus described by McGregor (1949) has been used by the author With it, any number of pictures may be taken at a rate of two to three per second

Whatever the method, desirable technical features are short exposure times (one-twentieth of a second or less) and either a moving grid or a very fine stationary grid to increase the contrast of the pictures Greater tube-film distances than 30–40 inches do not appear essential provided the tube focal spot is not large The possibility of obtaining two simultaneous sets of films in planes at right angles, e g simultaneous anteroposterior and lateral views, is worth consideration (Fredzill, 1950)

The rate of radiography

The radiographic methods fall into three broad groups in their application to the angiocardiography of congenital heart disease In the first group are those methods that give about one picture per second These provide valuable diagnostic evidence and anatomical information that aids the planning of surgery (e g by indicating the presence and size of vessels suitable for anastomosis)

But for a greater degree of diagnostic value, a more rapid series of films is indicated, probably two to six per second are desirable and methods capable of this rate comprise the second group An instance of this need is given by a child with transposition of the great vessels examined by the writer All the diodone had passed through the heart within two seconds Thompson (1949) showed how an aortic coarctation might be demonstrated only by chance with fewer exposures than two per second. Again, such is the variability of the normal outflow tract of the right ventricle during the cardiac cycle that a single film may give an erroneous impression of stenosis Multiple films showing this region filled may prove the apparent narrowing to be but a temporary phase

The third group of methods comprises those very rapid methods (Lind, 1949, Fredzill, 1950, Janker, 1950) that give ten or more pictures per second, they are more applicable to research work rather than routine investigations

The injection

The contrast medium is a 70 per cent solution of diodone, injected intravenously, usually at the elbow or groin For small children the amount can be based on the formula of 1.5 ml per kilogram of body weight In infancy about 10 ml are required, but an adult may need 40–70 ml It should be noted that such dosage is approaching the limit of tolerance

The necessity for rapid injection has been emphasized A relatively slow flow of diodone gives poor concentration in the heart and indifferent pictures, the chambers and great vessels may not be easily distinguishable one from the other since several will be filled at once The time for the completion of injection should be one second, over two seconds should be considered too slow With a large volume to inject, this is no mean feat The plunger of the syringe should move freely Its nozzle can be specially bored to have the widest possible channel The cannula tied into the vein should have the absolute

maximum size of lumen that is possible The solution and the syringe should be warmed to body temperature before use If they are too cold the diodone will crystallize out if too hot the plunger may not move freely in the syringe A convenient procedure is to tie the cannula into the vein while the patient is still in bed A stilette is inserted during transportation to the X ray theatre and until everything is ready

A preliminary radiograph to ensure correct exposure is advisable Generally speaking dark films are required so that trabecular detail of the ribs can be discerned through the shadow of the liver (Brocklebank, 1948) Then the diodone syringe is connected directly to the cannula (without any intermediary two-way tap to keep resistance to a minimum) and the injection made

Direct intracardiac angiocardiography Some investigators inject the contrast medium through a cardiac catheter whose tip lies in the superior vena cava or within the heart (Chavez 1947 Jönsson 1949) A pressure apparatus is necessary to make a rapid injection against the considerable resistance that is offered but by this means good intracardiac densities can be obtained The risk of the procedure because of the forceful jet of diodone impinging on the heart muscle and valves is greater than when the normal venous route is used

Anaesthesia

For adults simple sedation is sufficient and the examination may be conducted in the erect position

For children (except small babies) anaesthesia is generally required and the recumbent posture used Skilled anaesthesia with adequate oxygenation is essential The patient is often a bad risk his circulation is to be insulted by the rapid injection of a considerable volume of hypertonic fluid he may have a poor pulmonary circulation that for a time will be blocked almost completely by the bolus of contrast medium

Our own procedure is to sedate a child with rectal thiopentone before he leaves the ward for the X ray department When all is ready for the examination oxygen by mask is given and if necessary further thiopentone is injected intravenously through the tied in cannula As soon as the child is still (within two or three minutes) the diodone is injected and the series of pictures taken Following this intravenous nikethamide and continuation of the oxygen shorten the period of anaesthesia to the absolute minimum Oxygen is also continued during the return to the ward where the child is placed in an oxygen tent The anaesthetist always accompanies the patient and remains with him until he is fully conscious Under a well-given anaesthetic cyanosis is usually lessened and the time of danger is when muscular activity returns with its increased demand on circulating oxygen during the struggling phase that accompanies the regaining of consciousness

Dangers of the examination There is a small but definite risk greatest by far in cyanotic heart disease where the slightest upset may tilt the precarious balance between life and death If angiocardiography is reserved for such serious conditions the mortality rate has been estimated at nearly 2 per cent In the investigation of other diseases there is much less risk and in North America where the method has a wide application the death rate is under 0 3 per cent Dotter and Jackson (1950) who give these figures collected information about 23 angiocardiographic deaths of which 21 were in the study of congenital heart disease (17 with cyanosis) Eight occurred within ten minutes of the injection 9 between fifteen minutes and three hours and the remaining 6 between six hours and three days At autopsy sometimes pulmonary congestion and oedema or collapse were found but rarely was the cause of death revealed

The dangers to be considered are those of

1 Anaesthesia,

2 idiosyncrasy and toxic effects,

3 obstruction of an impaired pulmonary circulation by the bolus of contrast medium

As used for urography, idiosyncrasy to contrast media is very rare, Pendergrass (1942) found a death rate of only 0 0039 per cent in two-thirds of a million examinations In the angiocardiographic deaths described by Dotter and Jackson, sensitivity tests were performed in most instances and all were negative, which is evidence against the participation of an antigen-antibody reaction Gordon (1950) found no instances of acquired idiosyncrasy at delayed repeat examinations Nevertheless, it is probably advisable as a routine to perform a preliminary sensitivity test by the intravenous injection of 0 5 ml diodone In our experience intradermal tests are not accurate, they may be positive and yet no untoward reaction follows the intravenous injection of the drug

Toxic effects are likely if there is over-dosage or failure of elimination Therefore the procedure is contra-indicated if renal function is poor It is also contra-indicated by severe hepatic disease, since some of the diodone is eliminated by the liver, especially when there is associated kidney damage

In some of the recorded fatalities, convulsions have been noted This has been especially so when repeated injections of contrast medium have been given at a single session and when the aorta was partially or completely transposed, i e under conditions where the cerebral circulation received a very high concentration of diodone Broman and Olsson (1949) showed that altered cerebral vascular permeability is the probable cause It is therefore our practice always to confine the examination to a single injection, when a repeat is necessary, this is postponed to a later date To wait for only half an hour or so between injections is unsound, as high concentrations of the contrast medium are still circulating, indeed, it is possible to observe opacity in the renal pelvis in a radiograph taken as late as twelve hours after a single dose

The commonest form of death is respiratory arrest, immediately or shortly after the injection So far this has not been satisfactorily explained, possibly several factors are concerned, acting in a vicious circle

1 The pulmonary blood flow, often already impaired, is blocked for several seconds by the bolus of contrast medium

2 The blood pressure falls as a result of the vasodilation produced by the direct action of the diodone on the vessels This property is partly inherent in the drug and partly non-specific being related to the rate of injection and the elevated osmotic pressure (Gordon, 1950)

3 As a result there is stasis of diodone in the lungs, hindering oxygenation and altering the permeability of the blood vessels, to cause pulmonary oedema

4 The cerebral circulation often receives a high concentration of diodone for a relatively long period, vascular permeability is increased and direct action on the medullary centres depresses respiration

5 The effects of the diodone may be prolonged if the depressed blood pressure brings into play a temporary renal arterio-venous short-circuit *

* The writer has personal knowledge of two angiocardiographic deaths One occurred in a three year-old girl with Fallot's tetralogy, twelve hours after a single injection The post-mortem blood level of diodone was less than the calculated expected value But probably a renal arterio-venous shunt would only have to be effective for a short time for the vascular effects of the diodone to be aggravated

These factors which summate to produce respiratory failure must vary in their importance in different individuals In combating them it should be remembered that

1 Adrenaline as a restorative is contra indicated because it may cause pulmonary oedema (Elkeles 1948)

2 Such drugs as nikethamide are the stimulants of choice since they act directly on the respiratory centre

3 Artificial respiration as well as aiding the failing oxygenation of blood will ameliorate pulmonary oedema

Another risk of angiocardiography that must be considered is that of over-exposure to X rays Over irradiation of the patient is most unlikely in a single examination but as well as angiocardiography other radiological procedures (ordinary radiography fluoroscopy and cardiac catheterization) are likely to be undertaken and the total dosage of radiation administered in all these may be considerable (Hills 1950) The assistance of a physicist in checking the dosage is advisable Over irradiation of the medical team conducting angiocardiography is a perhaps greater risk that must be avoided Necessary precautions are

1 The use of a localizing cone that strictly limits the X ray beam to the picture area

2 The use of a radio-opaque screen between the patient and the doctor making the injection (a lead rubber curtain suspended from the tube-arm is convenient)

3 The wearing of protective aprons and gloves by all near the apparatus the anaesthetist in particular needs to wear gloves as his hands may be near the picture area

Morgan (1950) who makes the injection of contrast medium by means of a remote control pressure syringe has given diagrams of the typical distribution of stray radiation

Normal appearances The normal appearances of the heart and great vessels have been described by Dotter and Steinberg (1949) with idealized diagrams made after a study of over six hundred examinations

In children the writer has found that the right heart is shown between 0 5 and 3 5 seconds from the start of the injection the left heart and aorta are shown between 4 5 and 8 5 seconds But these times are variable and they tend to be a little longer in adults The speed of injection is also important as a trickle of diodone after the main bolus may prolong visualization

In the frontal projection the right heart is U-shaped The descending limb on the right is produced by the atrium The transverse limb is often indented on its lower border at the site of the tricuspid valve (just to the left of the mid line) to the left of this point is the inflow tract of the ventricle and the ascending limb of the U is its outflow tract This merges into the main pulmonary artery which divides so that its right branch covers the top of the U and its left branch turns sharply downwards The main artery and its left branch rather than the pulmonary conus comprise the middle segment of the left heart border (Miller 1950)

When the right atrium fills from the superior vena cava it is not unusual for some diodone to pass momentarily in a retrograde direction into the inferior vena cava and the hepatic veins The right ventricle does not usually fill as solidly as the atrium and it may not be possible to assess its size accurately Its appearance varies considerably with the phase of cardiac contraction

The left atrium lies in such a position that it is behind the gap in the U of the right heart—an important point since if both atria are filled because of a septal defect this gap is lost The shadow of the left ventricle follows the general line of the left heart border crossing the left atrium to the aorta

In the left anterior (or right posterior) oblique projection the four chambers are maximally separated and the interventricular septum is seen end-on The aorta is well shown

The lateral projection gives a profile delineation of the right ventricular outflow tract that is of value in the direct demonstration of a stenosis (although its constancy in several

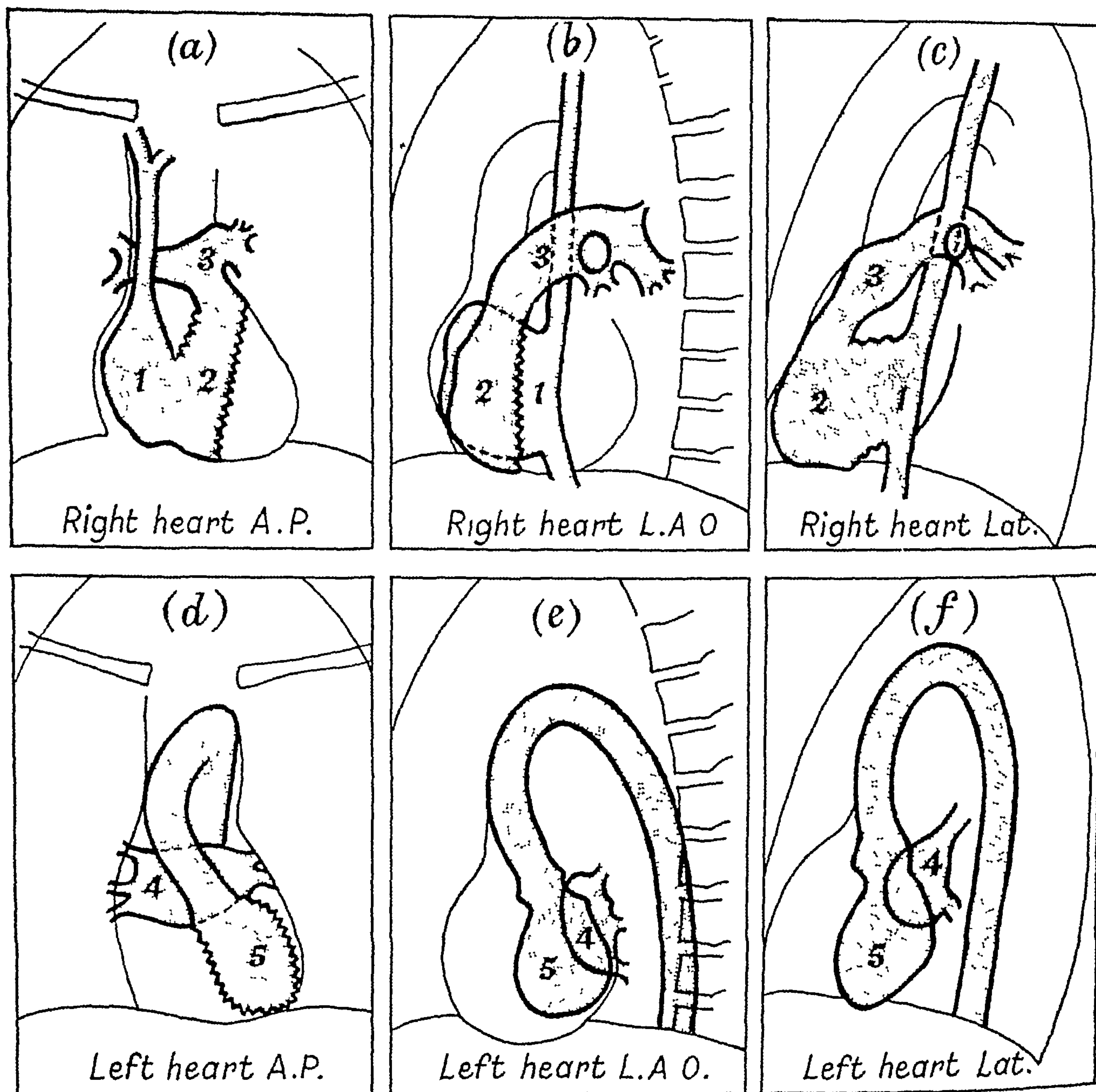


Fig 14 1—Normal angiocardiographic appearances (after Dotter and Steinberg).
1 = right atrium, 2 = right ventricle, 3 = pulmonary artery, 4 = left atrium, 5 = left ventricle These numbers are also used in subsequent illustrations

pictures is essential as the normal variations during the cardiac cycle may momentarily simulate a narrowing)

Congenital heart disease. It is in the study of this subject that angiocardiography finds its main application The method is not a substitute for such investigations as physiological studies and cardiac catheterization. But it is complementary to these, playing a significant part in the process of diagnosis and in the planning of surgical treatment Perhaps its greatest value lies in the anatomical information which it alone can give

Tetralogy of Fallot and allied conditions The angiocardiographic signs of the tetralogy of Fallot are

1 Simultaneous flow of diodone from the right heart into the aorta and into the main pulmonary arteries this is seen in the first three seconds

2 Delayed and decreased filling of the peripheral vessels in the lungs These secondary and tertiary branches are usually small the primary branches on the other hand fill early and may sometimes be normal in size or show post-stenotic dilatation

3 The direct demonstration of the pulmonary stenosis

4 A trickle of diodone may enter the left ventricle from the right through the ventricular septal defect

5 The heart empties in less than the usual time



Fig 14 2



Fig 14 3

Fig 14 2—Tetralogy of Fallot (age 4 years)

At 1 second after injection there is [illegible] filling of the main pulmonary arteries and of the aorta, which is [illegible] the right [illegible] subsequent films show reduced and delayed filling of the peripheral pulmonary vessels. The left pulmonary and left subclavian arteries appear very suitable for a Blalock's anastomosis. (Ao = aorta)

Fig 14 3—Eisenmenger's complex (age 8 years)

At 1 5 seconds there is simultaneous filling of the right arching aorta and of the large pulmonary arteries The right ventricular outflow tract [illegible] both in this [illegible] in the lateral projection. (T.N = tricuspid notch)

Often the diagnosis by simpler methods is not in doubt and the angiocardiographic evidence is only confirmatory Nevertheless the atypical case where every available item of evidence is necessary *does* occur and here angiocardiography is of diagnostic value

However its greatest value lies not as a purely diagnostic measure but as a routine pre-operative investigation to yield anatomical information viz

1 Whether or not both main pulmonary arteries are present the sizes and positions

2 The position of the aortic arch

3 The size and position of its main branches

The degree of over-riding of the aorta can be judged by the amount of diodone that passes into it and its branches. The direct demonstration of the pulmonary stenosis is not so certain, mainly because of the variability during the cardiac cycle of the outflow tract of the right ventricle. In the frontal projection it is perhaps preferable to judge its presence and assess its degree by observing the change in density of the lung fields produced by the diodone in the smaller pulmonary vessels. With a stenosis the increase in density is delayed in appearance and less than that seen in the normal subject.

The frontal projection is preferred by the writer because it gives the maximum anatomical information; the pulmonary and subclavian arteries of the two sides can be compared and their suitability for operation assessed. But if the presence of a pulmonary stenosis is uncertain, the examination can be repeated in the lateral position. This view gives a profile delineation of the right ventricular outflow tract; in the absence of a stenosis the likelihood of demonstration of its *normal* size is greater than in the frontal projection. An apparent stenosis demonstrated in this view must be interpreted with caution and must be constant in several films to ensure that it is a true stenosis and not a momentary phase. Distinction between infundibular and valvular stenoses is sometimes possible.*

In Fallot's tetralogy with pulmonary atresia the lungs may receive blood via a patent ductus arteriosus or the bronchial arteries. These vessels may also be employed when there is a persistent common arterial trunk. In such instances a gross right-to-left shunt is demonstrated but no main pulmonary arteries are demonstrable. Lung filling is poor. Campbell and Gardner (1950) have directly demonstrated the bronchial arteries, arising from the under-surface of the aortic arch or from the descending aorta. They fill later than the aorta and to some extent obscure the aortic window as they spread out fanwise in rather straight lines into the lungs. Precise delineation is difficult; they are best sought in the lateral or left oblique view. In the frontal projection, instead of the normal vascular hilar "comma", they produce nodular shadows that do not appear to connect directly with the outline of the heart.

In Eisenmenger's complex there are somewhat similar findings to those in Fallot's tetralogy as there is an interventricular septal defect and an over-riding aorta. But there is no pulmonary stenosis. The aorta and pulmonary artery fill simultaneously from the right ventricle; the pulmonary arteries are normal or increased in size. The frontal and, more convincingly, the lateral projection show a wide right ventricular outflow tract. Considerable peripheral lung filling occurs.

Tricuspid stenosis or atresia. In this condition, the flow of diodone is from the right atrium through a septal defect to the left atrium, thence to the left ventricle and aorta. Sometimes a rudimentary right ventricle fills from the left through a second septal defect. The pulmonary arteries fill later than the aorta, but they are usually small and little diodone enters the lungs; the main pulmonary supply may be by a patent ductus or enlarged bronchial arteries.

In the frontal projection the space normally occupied by diodone in the inflow tract of the right ventricle to the left of the tricuspid notch, is conspicuously empty in the early films but there is considerable opacity in the upper part of the heart shadow where both atria are filled at the same time. In later films, a rudimentary right ventricle may be seen

* An infundibular stenosis has been seen in which the length of the narrowing was so short and the situation so close to the pulmonary valve that distinction from a valvular stenosis was impossible by angiocardiography or by catheterization. Angiocardiographic determination of the exact type of stenosis has, in general, been disappointing.

to fill In the lateral view the non filling of the right ventricle in the early pictures is well seen anteriorly just above the diaphragm

The usual finding is that the flow of diodone into the lungs is poor information of the presence size and position of the pulmonary arteries is therefore useful pre-operative data If there is delayed flow from the right atrium to the left atrium the septal defect is probably small and its enlargement might be better treatment than the creation of an

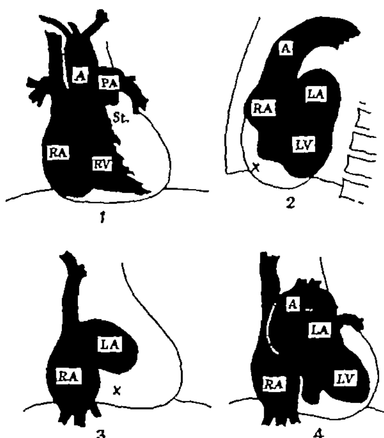


FIG 14 4

(1) Angiocardiographic appearances in Fallot s tetralogy (see Fig 14 2)

(2) The lateral angiocardiogram in tricuspid atresia
(X = site of non-filling of the rudimentary right ventricle)

(3) and (4) The frontal angiocardiogram in tricuspid atresia.
(X = site of non-filling of the rudimentary right ventricle in the early film later rudimentary chamber may be seen at this site)

artificial ductus If the examination shows that the tricuspid stenosis or atresia is complicated by complete transposition of the great vessels without pulmonary stenosis no benefit will result from an artificial ductus (Astley Oldham and Parsons 1953)

Isolated pulmonic stenosis The circulatory route is normal but the stenosis causes delayed filling of the smaller pulmonary vessels The main artery may show post-stenotic dilatation The heart empties slowly in contrast to the rapid emptying where there is an over riding aorta

The site of stenosis is best sought in the lateral *projection* If the patient is cyanosed there should be careful search for a right to-left shunt perhaps through the foramen ovale In routine radiographs a congenital aneurysm of the pulmonary artery may simulate post stenotic dilatation but angiocardiography in the lateral position will differentiate between the two conditions

As a rule, cardiac catheterization is the investigation of choice when isolated pulmonary stenosis is suspected

Complete transposition of the great vessels. Two types occur (Astley and Parsons, 1952), this agrees with the descriptions of other writers (Campbell, 1950), although Castellanos (1950) elaborates the classification to four types

In Type I the aorta appears in the frontal view to originate like the over-riding aorta of Fallot's tetralogy Type II is more common and quite characteristic, the aorta arises well to the left, over the outflow tract of the right ventricle It ascends towards the right at a variable inclination, in so doing often constituting the left middle segment



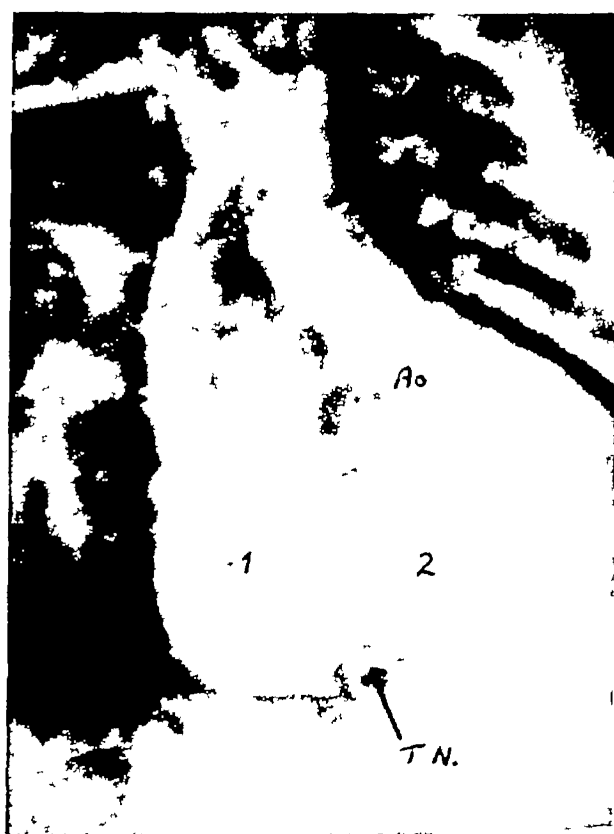


FIG 14 5 FIG 14 6

FIG 14 5—Complete transposition of the great vessels (age 3 years) 2 seconds
From the right heart the diodone enters the aorta, which is arising near the midline (Type 1) The main pulmonary artery is not identifiable and little diodone enters the lungs despite their congestion

FIG 14 6—Complete transposition of the great vessels (age 9 months) 0 5 second
As above, but the aorta originates over the right ventricular outflow tract (Type 2) This characteristic appearance is more common than Type 1

of the cardiac outline It arches over the left bronchus and descends just to the left of the midline, occasionally it arches over the right bronchus and descends more to the right In both types the diodone passes from the right heart in high concentration into the aorta and its branches The heart empties quickly, with little or no filling of the left chambers and lungs, the main pulmonary trunk is not demonstrable in the frontal view Since many, but not all of the children with complete transposition have grossly congested lungs, this lack of filling of such big vessels is a conspicuous feature

As Type II transposition, with the characteristic pattern in the frontal projection, is the common one this is the position of choice for the initial examination Repeated



(a)



(b)

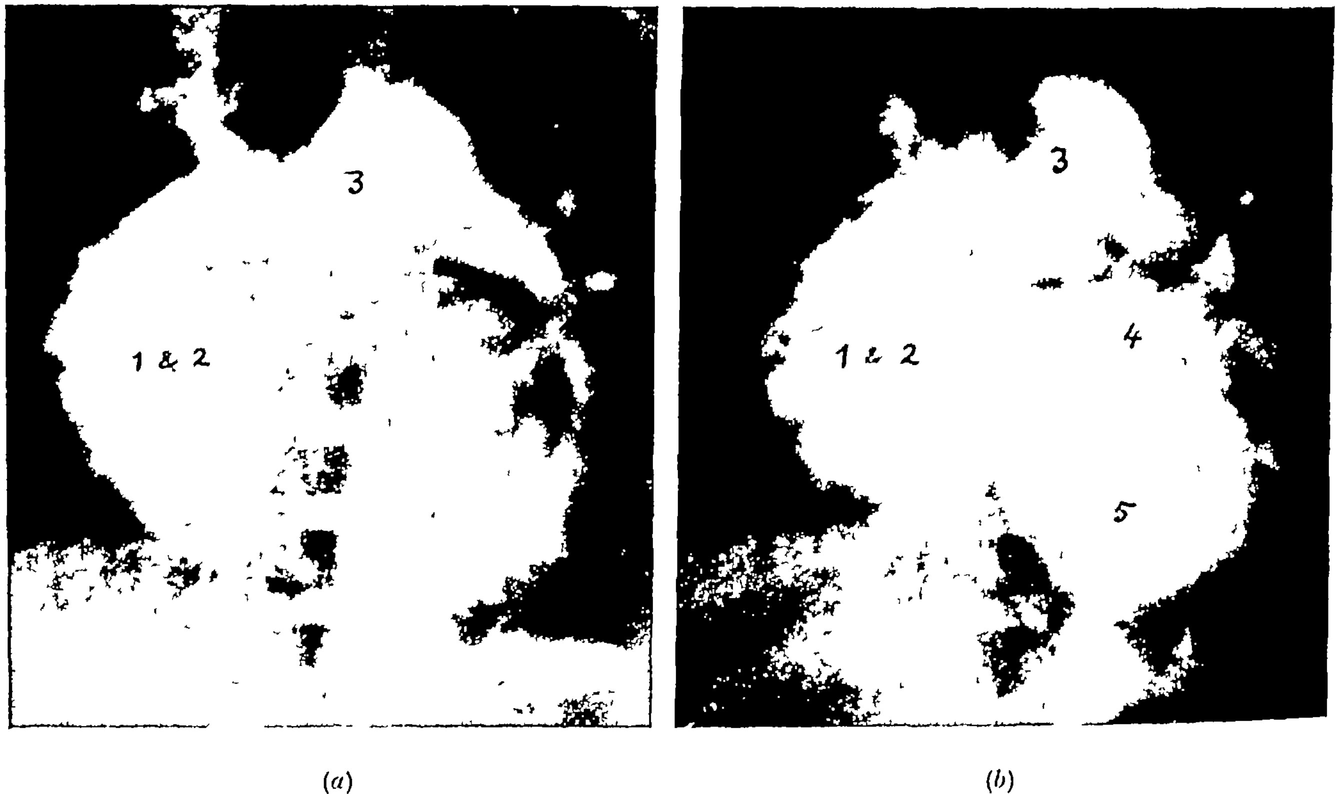
FIG 14·7—Interventricular septal defect (age 0 months) (a) 1·4 seconds (b) 3·0 seconds.
The circulatory route is normal, without trans-septal flow The pulmonary artery is larger than the aorta and there is pulmonary congestion.



FIG 14·8—Interatrial septal defect (age 5 years) 2·5 seconds.
The circulatory route is normal, without trans-septal flow The pulmonary artery is very large

injections of diodone at one session are not advisable as such high concentrations enter the cerebral circulation

Congenital lesions less suitable for demonstration. This group includes those conditions that are normally left-to-right shunts, i e isolated septal defects and patency of the ductus arteriosus In the case of a septal defect, the injection is unlikely to raise the pressure in the right side of the heart sufficiently to reverse the normal direction of shunt. Therefore diodone does not pass through the defect into the left heart This is especially so in the case of interventricular septal defects, which may be very large yet undemonstrable. However, when the diodone has passed through the lungs into the left heart it might be expected that some would return through the septum to the right and this may indeed be



(*a*) (*b*)

Fig 14 9—Interatrial septal defect (age 1 year), left oblique view (*a*) 1 second, (*b*) 1 5 seconds Trans septal flow from right to left has occurred between 1 and 1 5 seconds, giving direct evidence of the lesion This is an unusual occurrence in an isolated septal defect, but it is more likely to occur in infancy than in older subjects

observed to occur occasionally But the density changes are slight and unreliable of interpretation (because the contrast medium is already somewhat diluted after its passage through the lungs and because there may be lingering traces of diodone still in the right heart)

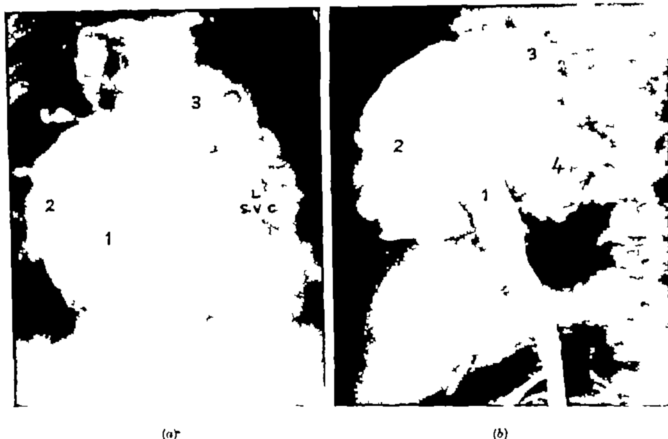
It should be explained again that the preceding remarks refer to *isolated* septal defects and not to those occurring as part of more complicated conditions, where they are frequently demonstrable Nor do these remarks imply that an isolated septal defect is *never* demonstrable (see Fig 14 9), but only that demonstration cannot be relied upon. There appears to be greater chance of success under the age of one year

The signs of a patent ductus are also unreliable The main pulmonary artery may show persistent opacity or re-fill from the ductus after normal emptying—but the density changes produced are uncertain of interpretation The ductus itself is occasionally seen —but more frequently a maze of pulmonary vessels obscures the area. There is often a

bulge in the aorta at the sight of insertion of the ductus but it is not constantly present nor is it absolutely indicative of patency

Should certain angiocardiographic demonstration of a ductus arteriosus be desired the use of retrograde aortography which is highly successful is indicated this will be described later (p 346)

Venous anomalies It is not uncommon to find variations in the anatomy of the great veins information concerning which may assist the surgeon The superior vena cava for instance may lie on the left or it may be bilateral



(a) (b)

Fig 14 10 —Bilateral superior vena cava ; abnormal cardiac rotation

(a) 3 seconds The right atrium lies medial to the right ventricle, which occupies the right cardiac border The left vena cava (L.S.V.C.) enters the coronary sinus and the right vena cava enters normally The book-like structure medial to the left vena cava is due to retrograde filling of the azygos vein Later films showed the left atrium to occupy the gap between the right atrium and the left vena cava (Injection at left elbow)

(b) 4 seconds (left oblique view). The right atrium lies behind the right ventricle and the tricuspid valve is abnormally high in position. The figure 4 indicates the site of the left atrium as shown by later films. (Injection from the groin.

One or more of the pulmonary veins may drain into the right atrium (usually via the superior or inferior vena cava or the coronary sinus) When all the veins drain into the right heart survival past infancy is rare on the other hand if only one vein is abnormal symptoms are unlikely There is usually a small associated interatrial septal defect Such veins may be demonstrated as abnormal vessels from the lungs to the right heart which fill with diodone during the period of filling of the left heart A laterally convex vascular shadow parallel to the lower right cardiac border has been described as a form which may be seen on the straight radiograph and identified by angiocardiography (Cnshman 1949)

Coarctation of the aorta The aorta is well demonstrated between five and nine seconds from the start of injection The left anterior oblique view shows a left aortic arch

maximally unfolded but the site of coarctation is often projected over the spine in this view Therefore the lateral position is preferable The information provided may

1. Confirm the diagnosis (important in the early years of life)
2 Indicate the calibre of the aorta above and below the coarctation
3 Show the character, degree, length and situation of the narrowing
4 Show the position of aortic branches relative to the narrowing
5 Show the post-operative condition, post-operative aneurysms have been demonstrated (Salen, 1948)

The radiographic appearances are closely related to the operative findings, they may indicate whether surgery is possible and help in its planning Thus a long, slowly narrowing stenosis is more difficult at operation and with other unfavourable circumstances may mitigate against surgery Multiple (inoperable) stenoses are occasionally present and prior knowledge of the condition will save fruitless thoracotomy

If a good venous injection fails to produce adequate density in the aorta (e g where there are other associated cardiac defects or where there is a very large heart), retrograde aortography will give better pictures

Acquired cardiovascular disease ; mediastinal tumours. Most types of acquired heart disease have been studied but practical application is limited In rheumatic disease the identification of thrombi within the chambers might aid treatment A pericardial effusion can be demonstrated easily (Dotter, 1949, Williams, 1949) by observing an increase in the space between the right atrium and the right lung (normally not exceeding 2–4 mm) In constrictive pericarditis very slow circulation through the heart may be found—in one instance described by Jonsson (1949), the diodone had not reached the left heart by 11 sec Masses adjacent to the heart can be differentiated from pericarditis

The method is of value in the early diagnosis of syphilitic aortitis (Dotter, 1949) The signs are increased diameter of the aorta (over 38 mm in its mid-ascending position), an irregular lumen (the variations are less gradual than with non-syphilitic causes, dilatation and irregularities may be shown in relatively inaccessible sites such as the sinus of Valsalva), tortuosity of the aorta (produced also by arteriosclerosis but a sign of value in the younger subject where degenerative disease is unlikely), variations in the thickness of the aortic wall (normally 2 mm), the presence of an aneurysm

An aneurysm ordinarily becomes opaque at the same time as its vessel of origin, so that its nature becomes apparent On rare occasions, clot or a narrow neck may impede filling

Distinctive changes have been observed in dissecting aneurysm (Golden, 1949) The aortic lumen is more or less abruptly narrowed and the aortic walls are thickened at the site of the dissection Contrast medium may penetrate within the false passages

By ordinary methods the differentiation of an aneurysm from a mediastinal tumour may be difficult For instance, a tumour close to a pulsating structure may itself appear to pulsate but an aneurysm may *not* pulsate In such cases angiocardiography can give otherwise unobtainable information (Sussman, 1947, Dotter, 1949) A mediastinal tumour does not usually impair the integrity of the great vessels, except by compression or displacement unless there is malignant infiltration, which produces irregular constriction or occlusion (in the X-ray appearance akin to that of malignant disease of the gut)

In addition to diagnostic value, delineation of the structures bounding a mass (preferably in two views, to give maximum three-dimensional information) aids the planning of operative attack Obstructive lesions at the thoracic inlet are particularly easy to demonstrate

Pulmonary disease Many pulmonary diseases have been investigated by angio ardiography A condition in which the method is particularly helpful and one which is minently amenable to surgery is a pulmonary arterio-venous fistula At 1½–2 seconds fter injection a large vessel is seen entering the often small pulmonary mass and a little ater at 2–4 seconds a similar vessel is seen leaving it Sometimes more extensive vascular ommunications may be shown

De Carvalho (1950) has determined the normal circulation times in the various pul nonary lobes and another interesting application has been the study of the surprisingly normal form and function of the remaining lung tissue after pneumonectomy (Neuhof, 1948)

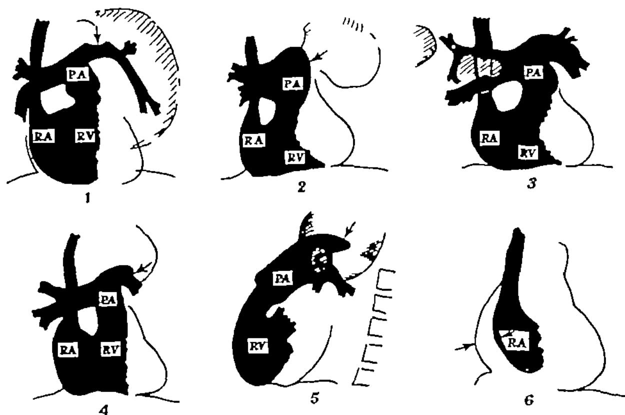


Fig 14 11 —Angiocardiographic evidence of inoperability of bronchial carcinoma (after Dotter Steinberg and Holman, 1950)

The arrows indicate neoplastic involvement of the pulmonary arteries Top right shows a mediastinal secondary deposit from a peripheral primary carcinoma bottom right shows pericardial invasion (note the wide space between the arrows).

Angiocardiography may help the diagnosis and prognosis of bronchial carcinoma (Neuhof 1949 Steinberg 1950) Infiltrating malignant lesions surround or engulf the neighbouring vessels producing irregular alterations in the outlines of the larger arteries and occlusion of the smaller ones Circumscribed tumours however only displace the adjacent vessels Exceptions occur—a malignant tumour is occasionally so circumscribed that it displaces rather than engulfs and a chronic inflammatory process may sometimes obliterate vessels

Perhaps the greatest value of the investigation in bronchial carcinoma is to assess prog nosis Dotter *et al* (1950) have given the following criteria of inoperability

1 Partial or complete occlusion by tumour of the left pulmonary artery within 1½ cm of its origin or of the right pulmonary artery proximal to its bifurcation

2 Partial or complete occlusion of the great mediastinal veins due to tumour in the mediastinum

3 Displacement and deformity of vascular structures by mediastinal metastasis in the presence of a known peripheral cancer

4 Demonstration of pericardial invasion

They prefer the frontal view for the right pulmonary artery and the left oblique for the left pulmonary artery (i e the vessels are observed sideways-on)

Absence of angiocardiographic evidence of inoperability does not mean the lesion is operable , on the other hand, evidence of inoperability must be convincing to be significant

They maintain that no patient should be denied exploratory surgery on the basis of the angiocardiographic appearances alone But they find the additional evidence yielded enables the planning of the most suitable approach , it informs the surgeon of otherwise hidden structures behind the tumour and reduces the duration of protracted explorations

Retrograde aortography

As already stated, the diagnosis by angiocardiography of a patent ductus arteriosus is not reliable Also, in certain circumstances the demonstration of an aortic coarctation may not be entirely satisfactory To overcome these difficulties very successful use has been made of retrograde aortography (Radner, 1948 , Broden and others, 1948–50) This examination, however, provides greater hazards than angiocardiography

Diodone is injected into the aorta by one of three methods, viz

1 Via an artery such as the carotid, axillary or brachial, reaching the aorta against the normal flow of blood

2 Directly into the aorta by a special cannula inserted percutaneously into and down the carotid artery (Jonsson, 1949)

3 Directly into the aorta by a cardiac catheter that has been inserted along the radial artery

The first method, against the normal flow of blood, can only fill the aorta adequately in infants Under one year it is sometimes possible to demonstrate a coarctation thus In older subjects only an indirect sign, namely, demonstration of the collateral circulation, will be achieved

Injection via a catheter inserted along the radial artery into the aorta is probably the most applicable route Because of the resistance of the catheter a rapid injection is best obtained by the use of a pressure apparatus (Jonsson, 1949) For demonstration of a coarctation the catheter need only reach the aorta at the origin of the innominate artery, but when a patent ductus is suspect the catheter tip should lie well down into the ascending aorta If there is a patent ductus, diodone passes into the pulmonary arteries , such an alternative diagnosis as that of aneurysm of the sinus of Valsalva that has ruptured into the right ventricle or congenital aortic septal defect may be made if the catheter tip is in this position

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CHAPTER 15

CARDIAC CATHETERIZATION

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The human heart was first catheterized by Forssman in 1929, who courageously introduced a radio-opaque catheter into a superficial vein of his own arm and advanced it into the right auricle The technique was devised for the intracardiac administration of stimulants and was later employed to visualize the heart and pulmonary vessels by injection of contrast material

In 1870 Fick showed that the cardiac output, expressed in litres per minute, could be estimated by dividing the oxygen consumption of the organism, expressed in c c per minute, by the difference in oxygen content of a litre of arterial and mixed venous blood This has come to be known as the direct Fick principle The oxygen consumption of the subject and the oxygen content of the arterial blood are readily estimated, but a truly mixed sample of venous blood can only be obtained from the right heart chambers or pulmonary artery It was this latter obstacle which prevented application of the direct Fick principle in human physiological studies until 1941, when Cournand and Ranges employed Forssman's technique of cardiac catheterization to obtain mixed venous blood from the right auricle

This new method was cautiously applied, but it soon became apparent that initial fears of massive venous or intracardiac thrombosis were unfounded, and intensive study of the human cardiac output in health and disease was then undertaken by many workers It was found that errors in determination of the cardiac output may arise from incomplete mixing of the venous blood in the right auricle as a result of stream-lining within the great veins and the influx of very unsaturated blood from the coronary sinus into this chamber To overcome this difficulty, mixed venous blood was obtained from the cavity of the right ventricle by passing the catheter tip through the tricuspid valve, but here efflux from the Thesbian veins occasionally caused considerable error. Dexter and his associates finally demonstrated that consistent values for the oxygen content of consecutive samples of mixed venous blood could be obtained only if the catheter tip lay within the pulmonary artery because here alone was mixing invariably complete

The ability to manœuvre the cardiac catheter through the chambers of the right heart into the pulmonary artery with relative ease and impunity greatly widened the scope of this new method of investigation The information which may now be obtained by use of this procedure will be briefly summarized

The radio-opaque catheter—manipulated as a probe under visual control—will define the course of the great vessels entering and leaving the right heart chambers, and may be used to delineate the size and position of the right auricle and ventricle Congenital defects of the atrial or ventricular septa may be demonstrated by its free passage into the left auricle or aorta

The mean pressures and pressure waves within the right heart chambers and pulmonary arterial tree can be measured and recorded by attaching a saline or electrical manometer to the cardiac catheter Valuable information on the haemodynamics of the pulmonary

circulation has been obtained in this way and pulmonary arterial hypertension may now be recognized long before clinical radiological or electrocardiographic findings make its presence manifest Comparison of right ventricular and pulmonary arterial pressures is of great value in confirming the presence of congenital pulmonary stenosis and localizing its position.

Truly mixed venous blood samples can be obtained simply and safely through the cardiac catheter and the cardiac output may be determined at rest and during exercise by application of the direct Fick principle Comparison of the oxygen content of blood samples taken from the pulmonary arterial tree right heart chambers and venae cavae in subjects with congenital heart disease provides valuable information upon the site and approximate size of abnormal shunts of fully oxygenated blood from the left side of the heart septal defects and patency of the ductus arteriosus may be differentiated in this way when the clinical findings are equivocal Comparison of the oxygen content of blood samples taken simultaneously from the right heart and a systemic artery in congenital cyanotic disease makes it possible to estimate the relative and absolute size of the systemic blood flow and the flow of mixed venous blood to the lungs—information which is invaluable in the pre-operative assessment of these patients

A special electrode-catheter may be employed to take intracardiac electrocardiographs but at the present time this is a purely research technique and has little clinical application

The rapid strides taken by thoracic surgery in recent years have made accurate diagnosis and assessment of congenital and acquired cardio pulmonary disease an essential preliminary to surgical treatment Cardiac catheterization—primarily a research technique—now holds an established place in this field of clinical activity

Technique

Materials

Cournand s cardiac and great vein catheters are extremely radio-opaque and easily manipulated when at body temperature Size 8F 100 cm in length are convenient for general purposes whilst Size 6F may be employed in young children and infants where the superficial veins are poorly developed The catheters are sterilized by autoclaving or formalin vapour and are stored and sterilized loosely coiled to maintain a natural curve which facilitates their passage into the heart To increase manœuvrability the terminal 2·0 cm is moulded to an angle of 45 degrees by a blunt stylet which is removed before use The catheters must be free from all traces of old blood before autoclaving otherwise pyrogenic reactions may occur

A slow infusion of heparinized saline is maintained through the catheter to keep the lumen free from blood It is advantageous to take blood samples and pressure measurements without the need to detach the catheter from the infusion apparatus and to achieve this some form of tap manifold is required Manipulation of two or three taps in the semi darkness frequently leads to confusion and personal experience has shown that a single four way tap is preferable to a manifold The tap employed at the Queen Elizabeth Hospital (see Apparatus) will connect the catheter in turn to the infusion apparatus saline manometer electrical manometer and blood sampling syringe and also enables the saline manometer to be primed from the drip bottle and permits calibration of the electrical manometer against the saline manometer When the infusion is maintained through the catheter the electrical manometer is automatically zeroed by connection to the adaptor for blood sampling

Intracardiac pressures are most simply measured by a saline manometer which consists of a glass tube, 100 cm in length and 2 0 mm internal diameter, mounted vertically upon a centimetre scale It is connected to the four-way tap by a length of rubber tubing and is filled with heparinized saline from the drip bottle before each pressure reading is taken to avoid influx of blood into the catheter

The saline manometer will only record mean pressures and in order to measure and record systolic and diastolic pressures within the right ventricle and pulmonary artery it is necessary to employ an electrical or optical manometer system which will respond faithfully to frequencies of 15 to 20 cycles per second This requires a rigid manometer system and many suitable electrical manometers have been designed and are available for this purpose. A mechano-electronic transducer manometer (see Apparatus) is personally employed in conjunction with a cathode-ray oscilloscope and recording camera Catheter vibration, set up by vigorous contraction of the right ventricle, frequently distorts records of the pressure pulse taken from the pulmonary arterial tree and it is always necessary to introduce some form of mechanical or electrical damping to the manometer system to eliminate these high-frequency artefacts

Intracardiac pressure measurement is made by reference to atmospheric pressure, and the horizontal plane of reference or zero level for the manometer should, ideally, pass through the catheter tip Since the position of this is variable, a fixed manometric zero is employed, and this zero is usually defined as the horizontal plane passing through a point 5 0 cm dorsal to the manubrium sterni with the subject in the supine position For convenience, the manometric zero may be fixed permanently at 10 0 cm above the top of the screening table, and any small correction between this level and the normal plane of reference can be made by measuring the anteroposterior diameter of the subject's thorax whilst supine

Arterial samples may be obtained through a medium bevel 20-gauge needle, but if repeated samples are required an indwelling needle is placed in one of the brachial arteries Riley's modification of the Cournand needle is suitable for this purpose

Accessory equipment which will be required includes cutting-down instruments for exposure of the vein, all-glass syringes of 10 or 20 ml capacity for the blood samples and sterile towels, gowns, masks and gloves (see Apparatus)

If the investigation includes estimation of the cardiac output, it will be necessary to measure the oxygen consumption of the subject A three- to five-minute collection of expired air into a Douglas bag is the most reliable method to employ The volume of the expired gas must be measured in a gas meter and samples analysed for their oxygen and carbon dioxide content in a Haldane or Sleigh gas analysis apparatus Alternatively, a Benedict spirometer with carbon dioxide scrubbers may be used to give a less accurate measurement of the oxygen consumption

Methods

Preparation of the patient A preliminary examination of the superficial arm veins should be made Cardiac catheterization is performed more easily through the left arm and a superficial vein in the ante-cubital fossa or proximal forearm which drains into the basilic vein is chosen Attempts to enter the thorax through the cephalic venous system are usually unsuccessful and if suitable veins are not present in either arm the right external jugular or saphenous vein are used

A simple account of the procedure is given to the patient if he is old enough to co-operate but explanations are limited to what will be seen and details are not discussed.

Prophylactic penicillin is given for 48 hours to cover the investigation, and quinidine

sulphate 3 to 6 grains according to age is administered 30 minutes before the commencement

For adults and co-operative children sodium amytal 3 to 6 grains is the only sedation necessary Subjects with chronic pulmonary disease do not receive more than 3 grains of this drug Rectal avertin or thiopentone or a combination of the two is used in children who are manifestly unco-operative and it will be necessary to co-opt the assistance of an anaesthetist for this purpose Volatile anaesthetics or the intermittent use of oxygen by the anaesthetist during the investigation will invalidate the results obtained from blood gas analysis

Assembly of the apparatus The operator wears a protective lead apron sterile mask gown and gloves

The sterile towels, cutting-down instruments arterial needle cardiac catheter and sampling syringes are laid out The syringes are lubricated with sterile liquid paraffin and three drops of heparin added to each and all air expressed The four way tap and electrical manometer—previously sterilized and rendered air free by immersion in boiling water for twenty minutes—are mounted on the supporting stand A transfusion set is assembled with normal saline containing 500 units of heparin per pint and connected to the four way tap The saline manometer—sterilized by autoclaving in a protective metal case—is connected to the four way tap and filled from the drip bottle care being taken to exclude all air bubbles Manometric zeroes are checked and the saline manometer is adjusted to a pressure equivalent of 50 mm mercury it is then connected to the electric manometer by adjustment of the tap for calibration of the latter

When these preparations are complete the patient is placed comfortably upon the screening table and both arms freed from the gown

Introduction of arterial needle and catheter The skin of the right arm is cleansed and the brachial artery infiltrated with 2 per cent procaine A Riley needle is introduced and when a spurt of blood from it indicates that the vessel has been entered a blunt stylet is inserted into the needle which is then threaded well into the artery and strapped in position Adequate anaesthesia makes this procedure painless and guards against arterial spasm which will make the introduction difficult The arm is placed unsplinted by the patient s side

The left arm is cleansed and loosely fixed to an adjustable arm-splint The position of the selected vein is confirmed and sterile towels draped so that only a few inches of surrounding skin are exposed The area is well infiltrated with 2 per cent procaine and the vein exposed by the usual technique employing where possible a small incision parallel to its course The blunt stylet is removed from the end of the cardiac catheter which is uncoiled mounted on the four way tap and flushed with heparinized saline to remove all air The drip rate is then adjusted approximately at 30 per minute

The cleared vein is lifted by a loose cat-gut sling and incised and a small aneurysm needle slipped into its lumen with the left hand and gently lifted to make the incision gape The vein is again lifted by the cat-gut sling which rides over the fourth and fifth fingers of the right hand whilst the catheter tip is guided into it by the index finger and thumb of the same hand Once the tip of the catheter has entered the lumen the aneurysm needle is gently withdrawn and the catheter quickly advanced to the axilla A vein which is stretched by the catheter will offer such resistance to its passage that manipulation will be impossible A vein of suitable size may go into spasm and grip the catheter making manipulation both difficult and painful adequate sedation of the patient the liberal use of local anaesthetic and the avoidance of unnecessary trauma to the vein are the best prophylactics for this complication.

Manipulation of the catheter The catheter is manipulated under fluoroscopic control, and can usually be advanced freely and without subjective sensation into the right auricle Occasionally its passage may be arrested at the commencement of the innominate vein or it may pass into the neck via the internal jugular vein at this point , the catheter may pass into the contra-lateral innominate vein instead of entering the superior vena cava Should any of these difficulties arise the catheter is withdrawn slightly, the tip re-directed by rotation, and again advanced, repeating the manœuvre until the obstruction is by-passed or the false direction corrected

To enter the inferior vena cava, the tip is rotated towards the posterolateral wall of





FIG 15 1 FIG 15 2

FIG 15 1 —Catheter in right lung field

FIG 15 2 —Catheter in left lung field

Note that the left pulmonary artery arises posteriorly from the main stem

the auricle so that the catheter will pass in a caudal direction through the inferior vena caval opening

The right ventricle is entered by rotating the tip so that the catheter may advance obliquely across the cavity of the right auricle towards the tricuspid valve Once the ventricle has been entered the catheter tip frequently passes to its apex and there becomes entangled in the papillary muscles or trabeculae carneae , attempts to enter the pulmonary artery from this position will fail and may damage the endothelial lining and induce ventricular extrasystoles

The infundibular portion of the right ventricle is entered by directing the catheter tip gently against the septum or anterior wall until it turns in a cephalad direction If this manœuvre fails it should be withdrawn into the right auricle and the tip " bounced " off the inferior wall until the catheter is bent into a U within the auricle , vigorous rotation

will now flip it through the tricuspid valve with the tip directed towards the infundibulum and it can be advanced without difficulty into the pulmonary artery from this position

The natural curve upon the catheter usually directs it into the right main branch of the pulmonary artery and it can be advanced without difficulty into the peripheral field of the right lung To enter the left main branch it is withdrawn to the main stem and the tip directed posteriorily and to the left by rotation a manœuvre which is made difficult by the fully advanced position of the catheter and the free oscillation of its tip with each cardiac systole

In most investigations the catheter is passed immediately into the pulmonary artery and pressure measurements and blood samples are taken from the ventricle and auricle during its withdrawal When stenosis of the right ventricular outflow tract is present the catheter is not retained in the pulmonary artery longer than is absolutely necessary

Abnormal catheter positions

The coronary sinus The catheter may be inadvertently introduced into the mouth of the coronary sinus which opens upon the posteromedial wall of the right auricle proximal to the medial cusp of the tricuspid valve It will advance freely up the sinus passing into the great cardiac vein until its tip reaches the left border of the heart shadow at the level of the left auricular appendage This course may be mistaken for a passage into the infundibular portion of the right ventricle and attempts to catheterize the pulmonary artery from this position are not unnaturally unsuccessful

When this occurs the catheter shows a sharp angulation at the point of entry into the sinus and the portion within the sinus shows a bodily movement towards the apex of the heart with each systole which results from the attachment of the sinus to the atrio ventricular septum When the catheter advances up the great cardiac vein its tip lies superficially and is subepicardial in contrast to the infundibular position which lies well within the heart shadow These points enable catheterization of the sinus to be recognized immediately by its fluoroscopic behaviour but if doubt is still present a blood sample will show a very low oxygen content and saturation

The aorta In the tetralogy of Fallot and complete or partial transposition of the great vessels the catheter may enter the aorta during attempts to advance into the pulmonary artery When this occurs the catheter will advance without conforming to the anatomical configuration of the pulmonary arterial tree It will pass up the innominate artery towards the subject s head or double back upon itself as it negotiates the arch and descends the thoracic aorta Pressure records and blood samples taken in these positions will confirm what has occurred It is occasionally possible to enter the aorta through a patent ductus arteriosus When this occurs the catheter appears to form a close loop within the pulmonary artery the tip passing backwards and medially as it enters the descending aorta If the pulmonary arterial and aortic pressures are identical it is sometimes difficult to determine whether the catheter has entered the aorta through a ventricular septal defect or a patent ductus In the former case the right subclavian and carotid arteries can be catheterized and the tip passes backwards and laterally as it negotiates the aortic arch

The left auricle The catheter may pass from the right auricle into the left auricle via a patent foramen ovale or atrial septal defect When this occurs the catheter will be seen to cross the heart shadow and enter the left side of the heart above the level normally occupied by the tricuspid valves The chamber which is entered will have a low pressure exceeding that of the right auricle by only a few millimetres of mercury When advanced further the catheter may curl up in the left auricle thus delineating its position which can

be confirmed by rotation of the subject into the first oblique position, or it may enter one of the pulmonary veins and pass into the peripheral lung field This free communication between the two auricles may be non-functioning and it is necessary to demonstrate the existence of a left-to-right or right-to-left shunt before its presence can be considered of significance

Other abnormal positions Anomalies of the systemic and pulmonary venous return occasionally accompany congenital cardiac defects The catheter may enter the right



Fig 15 3



Fig 15 4

Fig 15 3 —Catheter in right ventricle with its tip just below the pulmonary valves

Fig 15 4 —Catheter in coronary sinus and great cardiac vein
Note the position and direction of catheter tip

auricle through a persistent left superior vena cava and the coronary sinus when it is introduced through the left arm Anomalous pulmonary veins occasionally drain into the right auricle and if the catheter enters one it may pass through the wall of the right auricle into the lung field, this can be differentiated from catheterization of the azygos vein by the high oxygen content of the pulmonary venous sample It is possible to catheterize the pulmonary vascular bed without entering any cardiac chamber beforehand if the anomalous pulmonary veins drain into the superior vena cava

Taking blood samples

Adjustment of the tap connects the catheter to the sampling arm and 5 ml of blood diluted with saline lying within the catheter are withdrawn and discarded Ten to fifteen millilitres of blood are slowly withdrawn into an air-free heparinized syringe, which is then sealed with a wooden peg after the introduction of a small quantity of clean mercury The tap and catheter are cleared of blood by flushing with heparinized saline

Whilst taking an arterial sample the stylet is placed in hydrogen peroxide when the sampling syringe is connected to the needle

Blood gas analysis should be performed as soon as possible after sampling and syringes are stored in a refrigerator or iced water The manometric blood gas analysis technique of Van Slyke and Neill gives the most accurate results in trained hands

Pressure measurement

The catheter is connected to the manometer by appropriate adjustment of the tap The saline manometer must be well primed so that it discharges its contents into the catheter as it measures the pressure Passage of the catheter from a low to a high pressure chamber with saline manometer in circuit will cause a reflux of blood and blockage of the system by blood-clot but this will not occur if an electrical manometer is employed during catheter manipulation.

The pulmonary capillary pressure is measured by advancing the catheter into the lung field until it completely occludes one of the smaller pulmonary arteries A true pulmonary capillary pressure can only be presumed if the blood sample taken from this site has an oxygen saturation which equals that of normal arterial blood.

The pulmonary arterial pressure is measured in the main stem of the pulmonary artery or one of the main branches Critical damping of the electrical manometer is necessary to eliminate artifacts in the pressure curve which are due to catheter oscillation and pulmonary valve closure

The most satisfactory records of right ventricular pressure are obtained when the catheter tip is lying within the main cavity of the chamber Records from the infundibular portion of the ventricle are frequently distorted by occlusion of the catheter tip and the occurrence of extrasystoles Right auricular pressures are measured with the catheter tip in the centre of the chamber

All pressure curves will show a respiratory fluctuation which is greatest in subjects with dyspnoea and chronic pulmonary disease and which will be temporarily eliminated by breath holding

When the investigation has been completed the catheter is slowly withdrawn and the skin incision closed with a stitch which encircles the unligated vein The arterial needle is removed and the site of puncture gently occluded with one finger until oozing ceases

Complications of cardiac catheterization

Cardiac arrhythmias Ectopic ventricular beats are most frequently observed when the catheter tip is passing through the infundibular portion of the right ventricle but they rarely give rise to subjective sensations in the patient or operator Prophylactic quinidine sulphate is given to all cases to reduce ventricular excitability

Paroxysms of auricular and ventricular tachycardia have been reported and death from ventricular fibrillation has been known to occur Cournand reports that the passage of the catheter through a ventricular septal defect is frequently accompanied by bursts of ventricular extrasystoles

Without exaggerating the danger of inducing cardiac arrythmia it would appear prudent to avoid catheterizing patients with a previous history of paroxysmal tachycardia or clinical and electrocardiographic evidence of coronary ischaemia and if the information to be obtained from such cases warrants the procedure it is best performed with continuous electrocardiographic observation

Endocardial damage Careful post-mortem examination of the right auricle and ventricle of subjects who have died shortly after, but not consequent upon, cardiac catheterization does not reveal evidence of endocardial damage, but this is contrary to observations upon dogs

Fatal arterial embolism has followed catheterization of the left ventricle through a septal defect and was observed to have arisen from a mural thrombus. Retrograde catheterization of the left ventricle through the aorta carries the grave risk of coronary artery occlusion by the catheter tip and may result in sudden death from myocardial ischaemia

Pleural pain and slight haemoptysis occasionally follow cardiac catheterization and are presumably due to small emboli or areas of infarction These risks are probably greater in subjects with severe pulmonary hypertension where advanced degenerative changes of the pulmonary arteries are frequently present The risk of systemic air embolus is greatest when a congenital venous arterial shunt exists

Venous thrombosis A limited area of venous thrombosis may occur at the site of incision but rarely gives rise to more than transient discomfort Its incidence can be reduced by leaving the vein unligated Spreading thrombosis which involves the great veins is a rare complication

Pyrexia Prophylactic penicillin and a scrupulous aseptic technique are employed. Pyrexia which follows immediately on catheterization, occasionally with rigors, can be avoided by thorough cleansing of catheter and taps with hydrogen peroxide before sterilization

Cardiac catheterization is a benign investigation in careful hands in spite of this imposing array of complications Nevertheless, humanity must always temper the fierce spirit of enquiry

Interpretations of cardiac catheterization findings

Cardiac output

Normal values The cardiac output is estimated by use of the Fick principle thus,

$$\text{Cardiac output (litres per minute)} = \frac{\text{Oxygen consumption in c c per minute}}{\text{Arterio-venous oxygen difference in c c per litre of blood}}$$

The figure for arterio-venous oxygen difference is obtained by subtracting the oxygen content of the mixed venous blood from the oxygen content of the arterial blood. These values are normally expressed in c c of oxygen per 100 ml of blood and it is necessary to multiply by 10 for the purpose of this formula The cardiac output is normally determined with the subject at complete rest and in a basal state, and if these conditions are observed the oxygen consumption is an expression of the basal metabolic rate and will be proportionate to the age, sex and surface area of the subject It is therefore necessary to express the cardiac output in relation to the metabolic needs in order to obtain a figure which may be used for comparison, and this is done by relating it to body surface—cardiac output in litres per minute per square metre of body surface, the so-called cardiac index or by relating it to oxygen consumption—cardiac output in litres per minute for every 100 c c of oxygen absorbed

Provided that the oxygen consumption of the subject lies within the normal range for basal metabolic requirements the arterio venous oxygen difference—when expressed as a reciprocal—is a measure of the circulation rate In normal subjects at rest in the supine position, the arterio-venous oxygen difference has an average value of 4 40 volumes per 100 ml of blood with a range of 3 5 to 6 0 volumes per 100 ml When the blood has a normal haemoglobin content of 14 5 grammes per 100 ml the oxygen capacity will be approximately 20 0 volumes per 100 ml and an arterio venous oxygen difference of 4 4 volumes per 100 ml will be equivalent to an oxygen utilization of 22 per cent thus

$$\text{Oxygen utilization} = \frac{\text{arterio venous oxygen difference}}{\text{oxygen capacity of blood}} = \frac{4\ 4}{20\ 0} \times 100 = 22\ 0 \text{ per cent}$$

Normal arterial blood has an oxygen saturation between 97 and 94 per cent and therefore the mixed venous blood oxygen saturation will lie between 75 and 72 per cent with a range of 79 to 64 per cent

A change of posture from the supine to the erect position will reduce the venous return to the heart in the normal subjects and there will be a 25 to 30 per cent reduction of the cardiac output Adoption of the erect position does not significantly alter the oxygen requirements and the fall in cardiac output is mirrored by a reciprocal increase in the arterio-venous oxygen difference and the oxygen saturation of the mixed venous blood falls as a result of this change Subjects who exhibit marked anxiety during the investigation are found to have an increased resting cardiac output with an arterio-venous oxygen difference around the lower limits of the normal range and the oxygen saturation of the mixed venous blood will be high in consequence

The oxygen consumption may be increased to three or four times the normal resting value by light exercise upon a bicycle ergometer in the supine position A concomitant increase in the cardiac output will occur but this will not equal the increase in oxygen uptake and therefore the arterio venous oxygen difference will rise above the resting value This latter value rarely exceeds 7 5 volumes per 100 ml for this degree of activity Therefore the increased oxygen consumption made necessary by exertion is met partly by a rise in pulmonary blood flow and partly by an increase in the amount of oxygen which is absorbed by each unit of blood passing through the lungs

Abnormal values When the resting cardiac output is reduced the oxygen absorption from the lungs is maintained by elevation of the arterio venous oxygen difference above the normal range

In ambulant subjects with mild cardiac failure its output at rest will be normal or only slightly reduced and in subjects bed ridden with congestive failure it is rare for the cardiac output to fall below 50 per cent of its normal resting value unless death is imminent Therefore symptoms of failure will long precede any deviation of the resting arterio venous oxygen difference from normal

Cardiac insufficiency without manifest cardiac failure may be demonstrated by observing the response to exercise when the increased oxygen requirements cannot be met by a normal rise in cardiac output this deficiency must be off set by an abnormal increase in the arterio venous oxygen difference We have as yet insufficient data upon the expected rise in arterio-venous oxygen difference in normal subjects in response to graded exercise but when this information is available it may well prove possible to assess cardiac function by observations upon the arterio venous oxygen difference alone This would greatly simplify the pre- and post-operative assessment of subjects submitted to mitral valvulotomy

Table X shows the typical findings in a group of subjects with reduced cardiac output.

TABLE X

CHARACTERISTIC FINDINGS IN CARDIAC INSUFFICIENCY

Case	Age	Disease	Disability	Arterial blood		Mixed venous blood		Arterio venous O_2 diff
				O_2 con V %	O_2 Sat %	O_2 con V %	O_2 Sat %	
W C	33	Mitral stenosis						
		Resting	IIA	16 23	95	12 02	70	4 21
		Light exercise		16 79	98	8 24	48	8 55
A J	42	Mitral stenosis						
		Resting	IIA	17 50	94	13 30	71	4 20
		Light exercise				9 68	52	7 82
L T	46	Mitral stenosis						
		Resting	III	19 54	94	12 70	61	6 84
		Light exercise		19 77	95	6 84	33	12 93
A W	37	Mitral stenosis						
		Resting	III	19 48	87	8 62	38	10 86
		Light exercise		20 44	91	4 93	22	15 51
D C	30	Mitral stenosis						
		Resting	IV	17 32	89	8 29	43	9 03
D C	12	Mitral stenosis						
		Resting	IV	15 91	95	4 74	28	11 17
C McF	43	Idiopathic pulmonary hypertension						
		Rest	II(b)	13 55	92	7 95	54	5 60
		Light exercise				5 65	38	7 90
D S	39	Constrictive pericarditis						
		Rest	IV	16 35	90	8 97	50	7 38

High cardiac output An abnormally high resting cardiac output is frequently observed in severe anaemia, thyrotoxicosis, beri-beri heart failure, systemic arterio-venous aneurysm, Paget's disease, diabetic coma and some cases of cardiac failure secondary to chronic pulmonary disease

The hyperkinetic state is clinically recognized by a warm skin, rapid heart rate and high pulse pressure and may be demonstrated physiologically by a reduced arterio-venous oxygen difference

Interpretation of intracardiac pressures

All pressures, estimated by saline or electrical manometers, are expressed in millimetres of mercury with a zero reference point on the horizontal plane passing through a point 5 0 c m dorsal to the angle of Louis

Normal values Normal values are shown in Table XI Right ventricular pulse pressure is measured from the end of the diastolic phase to the height of systole The mean right ventricular pressure is modified by the relative lengths of the systolic and diastolic phases

of the cycle and will vary considerably with the heart rate Pulmonary arterial and right ventricular systolic pressures are equal

TABLE XI

NORMAL RIGHT HEART PRESSURES

(All values expressed in mm Hg)

	Systolic	Diastolic	Mean
Right auricle	—	—	2 to − 2
Right ventricle	18 to 30	2 to − 2	very variable
Pulmonary artery	18 to 30	7 to 12	12 to 18
Pulmonary capillary	—	—	6 to 12
Mean pulmonary minus pulmonary capillary	—	—	4 to 9

Respiratory variation 4 to 8
Right ventricular pulse pressure 17 to 27

All pressures will show a respiratory fluctuation of 4 to 5 mm Hg during quiet respiration In normal subjects the pulmonary arterial pressure does not rise with increases in cardiac output of three or four times the normal resting value

Pulmonary arterial hypertension The normal mean pulmonary arterial pressure is approximately 15 mm Hg and values which exceed 25 mm confirm the presence of pulmonary hypertension Pressures are occasionally observed which exceed those of the systemic arteries

The condition is frequently induced by left-sided heart failure secondary to systemic arterial hypertension coronary ischaemia or mitral stenosis When the left auricular pressure rises in such cases the normal pressure gradient across the pulmonary capillary bed can only be maintained by a concomitant rise of pulmonary arterial pressure This may expose the pulmonary capillaries to pressures which exceed the osmotic pressure of the blood proteins if a sudden gross imbalance between the functional capacity of the two sides of the heart occurs and will result in pulmonary oedema

In mitral stenosis elevation of the pulmonary capillary pressure reflects the rise in left auricular pressure which is necessary to maintain blood flow through the narrowed mitral valve and values between 15 and 30 mm Hg will be obtained in disabled patients The height of the pulmonary capillary pressure is determined by the size of the mitral orifice the volume of blood flowing through it and the diastolic filling time of the left ventricle On the basis of this relationship Gorlin (1952) and his colleagues have devised a formula to estimate the degree of mitral stenosis Early hopes that the wave form of the pulmonary capillary record would facilitate the recognition of significant mitral regurgitation have not been realized

In subjects with mitral stenosis long-standing and progressive left heart failure may be accompanied by increased resistance of the pre-capillary vessels of the lungs and thus will protect the capillary bed from excessive pressures which would otherwise be induced by sudden increases in the right heart output In these cases the pulmonary capillary pressure at rest is only slightly elevated and a large pressure gradient exists between it and the pulmonary arterial tree whose pressure is greatly elevated Provided that progressive and irreversible changes have not occurred within the pulmonary vessels the increased vascular resistance may be reversed by a recovery of left heart function These facts are of importance in deciding the suitability of subjects for mitral valvulotomy because if the operation is too long delayed permanent changes in the pulmonary vascular bed may cause a permanent limitation of the functional capacity of the heart

Similar changes in the pulmonary vascular resistance have been observed in congenital

cardiac defects where the pulmonary blood flow is greatly increased by intracardiac shunts Here, again, progressive obliteration of the pulmonary vascular bed will cause a steady reduction of the blood flow and the intracardiac shunt may eventually be reversed.

Intrinsic pulmonary disease may so increase the resistance of the vascular bed that pulmonary hypertension results. It is an occasional manifestation of chronic pulmonary fibrosis and emphysema It may result from a primary pulmonary arteritis—so-called idiopathic pulmonary hypertension—or follow progressive occlusion of the pulmonary bed by emboli or thrombosis from within or pressure upon the major vessels from without Pulmonary hypertension has also been observed when respiratory function is disturbed by gross skeletal deformities such as kypho-scoliosis

In cardio-pulmonary disease the pulmonary arterial pressure may be normal or only slightly elevated at rest and yet rise markedly with any increase in blood flow Conditions of this nature will only be recognized by observing the pulmonary pressure during exercise

When pneumonectomy is contemplated in subjects with chronic pulmonary disease, it may be of value to know whether the remaining lung can take the whole of the cardiac output without undue elevation of its arterial pressure, since such elevation carries the risk of acute or chronic right heart failure This information has recently been obtained pre-operatively by use of a double-lumen catheter which has a small balloon attached to the distal lumen The balloon, distended with contrast material, is used to occlude the main artery to the lung which is to be removed, whilst the proximal lumen of the catheter records the pressure induced in the arterial tree of the contralateral lung by this manœuvre.

Right ventricular systolic hypertension Right ventricular systolic hypertension is always observed when the pulmonary arterial pressure is abnormally high since the systolic pressure at these two sites is equal

Congenital stenosis of the pulmonary valves or right ventricular infundibulum is recognized by right ventricular systolic hypertension in conjunction with a normal or subnormal pulmonary arterial pressure When the stenosis is mild, the right ventricular systolic pressure may be normal, but the pulmonary arterial systolic pressure will be consistently below this value Differentiation between valvular and infundibular stenosis is frequently difficult but can sometimes be made by continuous pressure recording whilst the catheter is manipulated under fluoroscopic control

Right ventricular diastolic hypertension In right heart failure the filling pressure of the ventricle will be abnormally high and this is shown by elevation of the right auricular and late diastolic ventricular pressures

Elevation of the right ventricular filling pressure in constrictive pericarditis is associated with a low ventricular pulse pressure which results from a small stroke volume and normal pulmonary vascular resistance Diastolic hypertension will exist throughout the right heart chambers, pulmonary vascular bed and left auricle, and will be recognized by greatly elevated right auricular pressure with a normal or reduced gradient between this chamber and the pulmonary artery Table XII shows the findings in three examples of this condition.

TABLE XII

MEAN PRESSURES IN CONSTRICTIVE PERICARDITIS

(All pressures in mm Hg)

Case	Pulmonary "capillary"	Pulmonary artery	Right ventricle	Right auricle
1 A S	18	27	22 5	20
2 M M	—	23	22	17 5
3. R.W	31 5	37	34 5	27 5
4. D S.	27 5	32 5	31 5	25 0

Diagnosis of congenital heart disease

Recognition and localization of arterio-venous shunts Congenital atrial or ventricular septal defects and patency of the ductus arteriosus are frequently responsible for the passage of fully oxygenated blood from the left heart into the right heart chambers or pulmonary artery and its re-circulation through the lungs The presence and position of such communications are usually recognized by clinical and radiological examination but if doubt still exists and patency of the ductus arteriosus cannot be excluded catheterization of the heart may be undertaken as a diagnostic measure

Blood samples are withdrawn from the superior vena cava, right auricle main cavity and infundibulum of right ventricle and the pulmonary artery the oxygen contents of the samples are estimated and compared Comparison of such samples taken from a normal heart may show a variation of oxygen content which is due to incomplete mixing of the venous blood before it reaches the pulmonary artery and therefore any observed increase in the oxygen content of the blood passing through the right heart chambers must exceed the limits of normal variability before an arterio venous shunt can be diagnosed with confidence The following criteria are usually employed for a diagnosis which is based upon cardiac catheterization

Atrial septal defect The oxygen contents of right auricular right ventricular and pulmonary arterial blood exceed that of the superior vena cava by more than 2 0 volumes per 100 ml

Ventricular septal defect The oxygen contents of right ventricular and pulmonary arterial blood exceed that of the right auricle and superior vena cava by more than 1 0 volumes per 100 ml

Patent ductus arteriosus The oxygen contents of pulmonary arterial blood or its main branches exceed that of the right ventricle by more than 0 5 volumes per 100 ml If patency of the ductus arteriosus is complicated by secondary pulmonary hypertension the pulmonary valves may become incompetent and samples taken from the infundibulum may also have an abnormally high oxygen content

Differentiation between a patent ductus and high ventricular septal defect may be difficult on physiological grounds In septal defect the infundibular sample usually has the highest oxygen content since it is taken in the stream of the arterio venous shunt whilst samples taken from the right or left main pulmonary arteries usually have the highest oxygen contents in a ductus

It is impossible to distinguish between anomalous pulmonary veins entering the right auricle and an arterio venous shunt through an atrial septal defect on the results of blood gas analysis alone

When anomalous pulmonary veins enter the superior vena cava a sample from this site will have the highest oxygen content

It is unwise to diagnose an uncomplicated arterio-venous shunt unless the oxygen saturation of the pulmonary arterial blood is abnormally high

Diagnosis of cyanotic congenital heart disease

A proportion of the venous blood returning to the heart may pass through a congenital defect of the atrial or ventricular septa and enter the systemic circulation without perfusion of the pulmonary capillaries and when this occurs the oxygen saturation of the arterial blood will be reduced by venous admixture The condition is clinically recognized by a persistent cyanosis which increases with activity and is frequently accompanied by a secondary polycythaemia

Inadequate oxygenation of the blood perfusing the lungs may result from (pulmonary disease and occasional difficulty may arise in differentiating between (pulmonary disease and congenital heart disease as the cause of reduced arterial (saturation Inhalation of pure oxygen will lift the arterial oxygen saturation rap the normal range in chronic pulmonary disease whilst it will have little effect ı saturation which is reduced by venous admixture The carbon dioxide content arterial blood is a further aid to differentiation, for in chronic pulmonary disease dioxide retention lifts its arterial content above the upper limit of the normal rai volumes per 100 ml blood) whilst a congenital venous arterial shunt reduces the (content below the lower limit of the normal (45 volumes per 100 ml blood) by (hyperventilation

Primary and secondary polycythaemia may be differentiated in cases of doı estimation of the arterial oxygen saturation which will be normal in polycythaemı

When cyanosis is due to a congenital cardiac defect it is frequently necessary to the responsible deformity Isolated congenital defects of the atrial or ventriculaı are normally accompanied by an arterio-venous shunt which is produced by the pressures in the left heart chambers, but obstruction to the passage of blood in pulmonary vascular bed will reverse the direction of the flow A venous arterial may also result from anatomical displacement of the origin of the pulmonary arteı aorta, free mixing of venous and arterial blood in a common chamber or truncus arte or anomalous drainage of systemic veins into the left auricle Two or three oı deformities may be found in one subject

A precise diagnosis of the congenital defect was of little more than academic ı in the past, but the introduction of surgical treatment for the tetralogy of Fallo commonest form of congenital cyanotic heart disease—created the need for accura operative diagnosis

A physiological diagnosis of tetralogy of Fallot is based upon demonstration of a arterial shunt in association with a pulmonary valvular or infundibular stenosis presence of a collateral systemic circulation to the lungs and the free mixing of bloo both ventricles at the entrance to the pulmonary artery and aorta will prevent an ac estimation of the pulmonary blood flow, but if the blood leaving the pulmonary cap is presumed to be 95 per cent saturated with oxygen, the absolute and relative s the systemic blood flow and effective pulmonary blood flow can be estimated by modif of the direct Fick principle For purposes of calculation the right auricular blood is considered to be representative of the mixed venous blood

Let A = the oxygen content of arterial blood in c c per litre
MVB = the oxygen content of mixed venous blood in c c per litre
PV = the oxygen content of pulmonary venous blood in c c per litre calculated at cent of the oxygen capacity of the blood
O_2 = oxygen consumption of the subject in c c per minute

The systemic blood flow is defined as the amount of blood flowing to the tissues of th other than the lungs and is given by the formula

$$\frac{O_2}{A - MVB} \text{ litres per minute}$$

The effective pulmonary blood flow is defined as the amount of mixed venous blood through the pulmonary capillaries and is given by the formula

$$\frac{O_2}{PV - MVB} \text{ litres per minute}$$

The effective pulmonary blood flow is expressed as a percentage of the systemic blood flow by the formula

$$\frac{A - MVB}{PV - MVB} \times 10 \text{ per cent}$$

The venous arterial shunt is expressed as a percentage of the systemic blood flow by the formula

$$100 - \frac{A - MVB}{PV - MVB} \times 10 \text{ per cent}$$

It is not possible to estimate accurately the total pulmonary blood flow nor determine the relative contributions of the pulmonary artery and the collateral vessels to this flow

The severity of a congenital defect is inversely proportional to the size of the effective pulmonary blood flow and its capacity to increase with the needs of activity Reduced effective pulmonary blood flow may be associated with a normal or increased total pulmonary flow where the greater proportion of the blood circulating the lungs is derived from the left heart a condition which is represented in extreme form by complete transposition of the great vessels Severe pulmonary hypertension may co-exist with a reduction of both total and effective pulmonary blood flows a state which is observed in the terminal stages of the Eisenmenger complex and the reversal of arterio venous shunts by progressive increase of the pulmonary vascular resistance Therefore the demonstration of a reduced effective pulmonary blood flow in conjunction with a venous arterial shunt is insufficient physio logical evidence upon which to base a diagnosis of tetralogy of Fallot Proof of pulmonary stenosis must be obtained by measurement of the pulmonary arterial pressure and it must be remembered that when stenosis exists the presence of the catheter will cause further obstruction and give an observed value which is below the real pressure within the vessel

The physiological findings in tetralogy of Fallot closely resemble those in congenital pulmonary stenosis with atrial septal defect or patency of the foramen ovale and the following points will aid in differentiating these two conditions

In tetralogy of Fallot the right auricle and ventricle are not usually enlarged and dextra position of the aorta causes the pulmonary artery to lie abnormally close to the left border of the cardiac shadow Infundibular stenosis may be observed and a ventricular septal defect demonstrated by catheterization of the aorta Comparison of the oxygen content of right ventricular and auricular blood samples may indicate a left-to-right shunt through the ventricular defect With a direct communication between the two ventricles the right ventricular systolic pressure will equal that in the systemic arteries

In congenital pulmonary valvular stenosis with venous arterial shunt through an atrial septal defect or patent foramen ovale the right heart chambers are frequently enlarged and the pulmonary artery lies in its normal position within the heart shadow The stenosis will lie at the level of the valves and the artery is frequently dilated above it There will be no evidence of a co-existent left to-right shunt through a ventricular septal defect whilst the atrial septal defect may be demonstrated by passing the catheter into the left auricle blood from which will be incompletely saturated with oxygen There is no direct com munication between the two ventricles and it may be possible to demonstrate a significant difference between the systolic pressure in the right ventricle and that in the left ventricle or systemic arteries In severe cases the right ventricular pressure will exceed 200 mm Hg

Apparatus

Requirements for cardiac catheterization

Radio-opaque cardiac catheters 100 or 125 cm in length sizes 6 to 8 F These are stored dry and may be autoclaved in gauze lined circular metal containers 8 inches diameter and 2 inches deep

Fig 15 5 —General view of apparatus assembled for cardiac catheterization

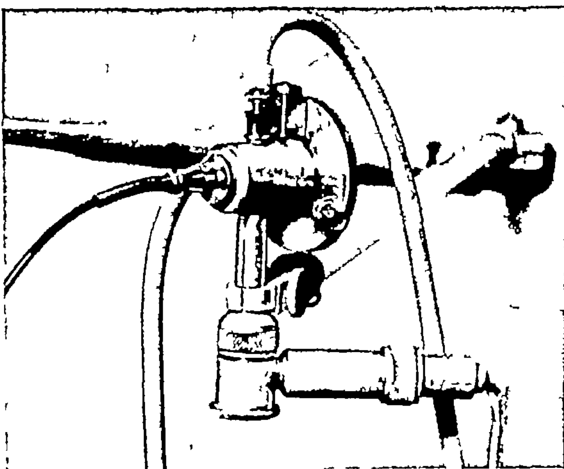


Fig 15 6 —Four way tap and mechano electronic manometer mounted on adjustable arm ready for use

Riley's modification of 20 gauge hypodermic needles for arterial puncture with blunt stylet.
The usual requirements for a cut-down intravenous drip transfusion
Sterile towels, gowns masks, caps and gloves
Two pint bottles of sterile normal saline containing 500 units of heparin per pint
Sterile gallipot and all glass syringe for flushing through catheter

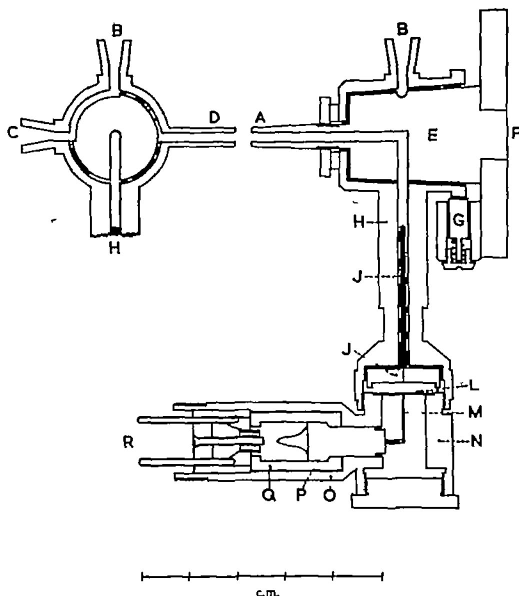


Fig 15-7—Scale diagram of tap and manometer

A Luer adaptor for cardiac catheter
B Record adaptor for intravenous drip
C Record adaptor for saline manometer
D Adaptor to take flexible connection for sampling syringe
E Tap.
F Circular tap handle
G Spring catch which engages in four recesses upon tap barrel to facilitate accurate location of tap position.
H Damping chamber
J J Damping needle The head is recessed to form the manometer chamber
L Manometer diaphragm fixed to manometer head.
M Stylus connecting plate of mechano-electronic transducer to manometer diaphragm.
N Detachable manometer head which incorporates
O Mechano-electronic valve mounting
P Mechano-electronic transducer valve
Q Dielectric valve insulation
R Three-point plug to connect valve to bridge circuit

Tap positions

1 Catheter to intravenous drip manometer chamber to sampling arm (manometric zero).
2 Catheter to saline manometer intravenous drip to sampling arm.
3 Catheter to transducing manometer intravenous drip to saline manometer
4 Catheter to sampling arm transducing manometer to saline manometer

A tap manifold to connect the catheter to intravenous drip, saline and electrical manometers and blood sampling syringes The four-way tap employed by the author incorporates the mechano-electronic pressure recorder, details of its construction are shown in Fig 15·7 Alternatively, three three-way stop-cocks with record mounts may be assembled in series for this purpose

Requirements for blood sampling and blood gas analysis

Ten sterile all-glass syringes, 10 or 20 ml capacity, lubricated with sterile liquid paraffin and supplied with wooden (tooth-pick) plugs A beaker of hydrogen peroxide to hold arterial needle stylet whilst blood sampling Heparin anticoagulant for blood syringes
Van Slyke Neill Blood Gas Apparatus, complete with pipettes and reagents for its use

Requirements for estimation of oxygen consumption

Douglas bag, 100 litres capacity, complete with three-way stop-cock, length of corrugated rubber tubing one-inch bore, two-way valve box, mouth-piece and nose clip for collection of expired air
Stop-watch
Gas sampling tubes 110 ml capacity, and mercury reservoir and tubing for their evacuation.
Barometer
One wet-type gas meter, 2 5 litres per revolution
One Haldane or Sleigh General Gas Analysis Apparatus and reagents for its use

Requirements for pressure recording

Saline manometer One 100-cm length of glass tubing, 2 mm internal diameter, which is conveniently autoclaved and stored in a brass container A meter rule fixed to the intravenous drip stand with spring clips to hold the glass tubing
Length of sterile rubber tubing to connect manometer to the tap manifold.
Spirit level mounted on 4-foot hardwood rod.
Electrical manometers Several capacitance pressure recording manometers with suitable amplifying circuits are on the market
The author employs a mechano-electronic pressure recorder which incorporates a mechano-electronic transducer (R C A valve 5734) Current variations are fed to the D C amplifier of an oscillograph through a balanced bridge circuit
Oscillographs A two- or four-channel direct writing oscillograph with D.C amplification is the most convenient instrument to employ, and enables simultaneous electrocardiographs to be recorded during the cardiac catheterization Alternatively, a cathode-ray oscilloscope with D C amplification and camera may be employed
The electrical recording manometers are expensive items of equipment and require constant skilled attention for trouble-free use They are not essential for routine diagnostic studies with the cardiac catheter

Additional requirements

Oxygen cylinder with flow meter and B L B mask
Hypodermic tray with usual stimulants and restorative drugs

The majority of the items listed here are standard hospital equipment, and apart from the electrical recording manometers the other apparatus is relatively inexpensive.

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CHAPTER 18

CONGENITAL ACYANOTIC HEART DISEASE

In this group patent ductus arteriosus and coarctation of the aorta represent the conditions most frequently referred for surgical correction and most amenable to operation but patent septal defects whether atrial or ventricular may one day be safely closed they are serious lesions but the methods devised by Murray (1948) for their closure have not been adopted widely and safe surgical measures await the perfection of techniques for providing a temporary extracardiac shunt

The surgery of the patent ductus arteriosus and of the coarcted aorta have been securely established and because of the poor prognosis in those not corrected surgery is often employed at an early age in both Stenosis of the pulmonary valves is being increasingly relieved by Brock s valvulotomy operation before cyanosis has developed (see page 402)

Developmental abnormalities affecting the aortic arch may by the encircling and strangling action of malformations such as the double arch produce obstruction of the trachea and oesophagus which may require surgical relief

Patent ductus arteriosus

This persistent channel between the aorta and the pulmonary artery which usually closes soon after birth (1–3 months) is an example of a congenital cardiac lesion unassociated with cyanosis until a late stage when and if a reversed shunt develops It is a typical left to right arterio venous shunt and usually the only defect present though in three of my operated series it has been associated with a septal defect in the auricle in one in the ventricular septum in one and with a mild degree of mitral stenosis in one In these three patients operation was done with the pre-operative knowledge that the other defects existed the indication being repeated attacks of disabling bronchitis and gross lung hyperaemia these have notably decreased since operation Occasionally it persists to maintain a blood supply to the lungs when the normal pulmonary blood flow is deficient or excessive

As the result of the full investigation of patients with cyanosis an increasing number of reversed shunts through a patent ductus are being detected Although this occurs most commonly in the age group of 30 to 40 years we have seen examples at younger ages Cardiac catheterization findings in these patients show that from time to time and under different conditions of activity the flow may be alternately from the aorta to the pulmonary artery and from the pulmonary artery to the aorta and much probably depends on the degree of hypertension in the lungs and the state of the left ventricle Whether the ductus should be tied under these conditions remains in doubt

In one patient of five (Parsons and d Abreu) a patent ductus arteriosus was present in conjunction with a congenital mitral stenosis associated with gross pulmonary hyper tension The pre-operative angiocardiographic and catheterization studies proved that blood was flowing from the pulmonary artery to the aorta At operation the ductus was temporarily occluded and a needle connected to a water manometer showed that the pressure in the pulmonary artery rose rapidly The ductus therefore was not tied but the mitral valve was explored through the usual atrial approach and a tight mitral stenosis detected and its anterolateral commissure split by the digital method

Patency of the ductus accompanies some examples of coarctation of the aorta The aortic end of the ductus lies distal to the origin of the left subclavian artery and the pulmonary orifice is a little to the left of the bifurcation of the main pulmonary trunk



FIG 16 1 —Diagram of persistent patency of the ductus arteriosus

The biological explanation of ductal closure or of persistent patency remains obscure With the expansion of the lungs after birth the blood flow previously diverted from the pulmonary artery to the aorta is required for lung function and is associated with a marked change in the pressure of the right and left side of the heart The foetal pressure in the right side of the heart exceeds that of the left and the reverse holds good immediately the lungs are inflated after birth The wall of the ductus is surrounded by a mass of muscle tissue which contracts though the activating stimulus is not known It is also suggested that the sudden increase in pressure in the aorta forces a fold of tissue across the aortic mouth of the ductus, none of which, however, explains the far greater tendency for patency to persist in girls than in boys The inherent tendency to close may not depend entirely on physiological reasons, e g it may close with a fatal result when it is the only channel by which blood goes to the lungs If the lung is slow to expand these features may all act more slowly and the ductus as a result may remain open If other abnormalities of the heart are present, e g. pulmonic stenosis, coarctation, the ductus may remain open as a channel of relief.

Pathological anatomy

The patent duct may be long and narrow, or so broad and short as to be stomal Its diameter is usually greatest at its aortic end The greater pressure of the aorta forces blood into the pulmonary artery, which becomes dilated and the pulmonary arteries themselves are often greatly widened, both changes may be well seen on radiological screening or on the plain radiograph, but *it is important to remember there is no " typical " X-ray appearance* The left ventricle tends to hypertrophy and dilate and infective bacterial endocarditis is a complication, the exact figures of which it is not possible to state The high incidence in Maude Abbott's series is partly explained by the material being gathered from autopsy findings From a surgical point of view far graver is the risk inherent in all types of arterio-venous fistula and most of these patients untreated die from heart failure, though odd cases undoubtedly survive to advanced old age The average age of survival in Maude Abbott's fatal cases was 24 years The effect of the shunt is to increase the work of both ventricles and to cause pulmonary hypertension.

The pulmonary artery under the constant high impact of the aortic stream may become truly aneurysmal and rupture if it has been infected, mycotic aneurysms of branches of the pulmonary artery may develop if the artery wall has been infected in the course of infective arteritis, or as the result of septic emboli.

Physiological studies

This is dealt with in fuller detail in Chapter 15 By estimating the oxygen saturation of the blood in the aorta, and in the pulmonary artery distal and proximal to the duct opening, it may be shown that 25 to 70 per cent of the total volume of blood expelled from

left ventricle may pass *across the shunt* An experiment was done on one of my patients Arnott the oxygen saturation of blood aspirated from the three sites being estimated



16·2.—Radiograph of a child of 7 years with a large patent ductus arteriosus.

e appearances represent an extreme degree of the condition a large pulmonary artery and extremely v scula lungs with rgement of the heart



Fig 16·3 —Radiograph of a patient of ?2 years with no cardiac murmur present large heart enlarged pulmonary artery and congested lung fields.

The diagnosis f p tent ductus wa established by cardiac catheterisation nd a large ductus tied at operation.

Calculation of volume of reflex through the patent ductus This was based on e work of Eppinger Burwell and Gross (1941) *An investigation into the blood flow* rough a patent ductus arteriosus was made on a patient who was admitted to the Queen lizabeth Hospital under the care of Professor Melville Arnott

Miss B R The patient was a girl of 17 years completely symptom free although she realized at something was amiss with her heart, because doctors had always remarked on it She as able to play games

Physical signs Typical machinery murmur with clinical and radiological evidence of nlargement of the heart the latter investigation also demonstrating a prominent pulmonary tery and congestion of the lung fields The blood pressure was 140/0 During the operation r closure of the ductus needles were placed in the aorta and the pulmonary artery distal and roximal to the entrance of the ductus approximately 20 c c of blood was withdrawn anaerobic lly from each The ductus was then doubly ligated and transfixed

Progress was uneventful the murmur disappeared and the blood pressure became 140 70

In patency of the ductus arteriosus the output of the right ventricle is made up of blood hich comes to this ventricle from the peripheral circulation and from no other source i e volume f peripheral blood flow and output of right ventricle are identical This can be calculated from he O_2 consumption per minute the O_2 contents of aortic and right ventricular blood

The output of the left ventricle consists of two components the blood from the right ventricle nd the blood entering the pulmonary artery by way of the ductus arteriosus These confluent treams pass through the lungs and reach the left side of the heart Since the blood entering the ung capillaries is thus only partly blood from the right ventricle the oxygen content of right

ventricle blood cannot be used in calculating pulmonary blood flow This calculation requires knowledge of the oxygen content of blood taken from the pulmonary artery at a point where mixture of the two streams is complete, i e as far distal as possible to the point where the patent ductus arteriosus discharged its reflux into the pulmonary artery The difference between the two outputs is obviously the volume of the reflux

Application of these principles to the patient under analysis Samples were withdrawn anaerobically just before the ductus was ligated At this time the anaesthetist considered the oxygen consumption to be around 200 c c per minute, while this figure cannot be very accurate, it is reasonably certain that it did not change during the sampling period Consequently, the absolute values may not be accurate, but the ratios are

Blood samples were analysed in duplicate in a Van Slyke-Fuchs apparatus

O_2 combining power of blood 19 33 vol per cent.

$$\text{Blood flow in (litres/min)} \quad \frac{O_2 \text{ uptake in c c /min.}}{\text{Arterio-venous } O_2 \text{ difference in c c /litre}}$$

Sample	Source of sample	O_2 content, c c per litre	A-V diff	Blood flow
I	Aorta	187 0	—	—
II	Pulmonary artery distal to ductus	167 7	19 3	10 36
III	Pulmonary artery proximal to ductus	154 7	32 3	6 19

Volume of reflux through ductus — 4 17
Volume of right ventricular output 6 19
Volume of left ventricular output 10 36

Cardiac catheterization Although clinical evaluation of the typical murmur and radiological screening provide the diagnosis without difficulty, in some instances cardiac catheterization is of great value when the murmur is entirely systolic in character as differentiation from patent auricular septal defect can then be established

In one patient with a large left ventricle and a diastolic pressure so low that it could not be recorded there was no murmur at all Physiological studies established the diagnosis and at operation a very broad ductus was ligated (Fig 16 3)

If catheterization is employed the mean pressure in the pulmonary artery is often very much raised, though occasionally it is only slightly above normal the pulmonary blood flow is naturally raised, usually three to four times the normal, and this increases the work of the left ventricle

A typical investigation of a moderately sized shunt was as follows

R W, aged 21 No real disability though the patient tired easily and the diastolic pressure was not greatly lowered

Oxygen saturation	75	per cent	in the right auricle
,,	,,	76	,, ,,	in the right ventricle
,,	,,	80 7	,, ,,	in the pulmonary artery
,,	,,	95 3	,, ,,	in brachial artery blood

The pressure in the pulmonary artery stem was 40/14 (mean 22) This is raised (normal mean 15, 25/10) The pressures in the right auricle and right ventricle were normal The calculated shunt is 24 per cent of the cardiac output

Angiocardiography is of little value in the diagnosis or estimation of a patent ductus arteriosus

Clinical features

The condition is commoner in girls than boys and usually without symptoms in childhood the diagnosis often being made at a routine school clinic examination or when the chest is being examined in the course of a respiratory illness If the duct is large there may however be dyspnoea stunting of growth and lassitude The children may show signs of undue fatigue after exercise and sleepiness during the day When symptoms are present the heart is always enlarged It is important to remember that even in infants symptoms may be severe because of the lung congestion and may require operation before the age of two (see Fig 16 5) Cyanosis is not present unless the shunt has become reversed

The development of infective endocarditis will produce a typical clinical picture Persistent and high pulmonary hypertension may in itself cause dyspnoea which in adults is not always relieved by operation as the hypertension may have caused irreversible changes

The diagnostic features

(a) The *murmur* and *thrill* Characteristically a thrill is palpable in the second left interspace below the clavicle and in this the pulmonary area there is usually audible the typical machinery murmur of Gibson it is loud low pitched and harsh and is heard both in systole and diastole though more marked in the former and is most intense in late systole and early diastole The systolic element of the murmur is widely transmitted over the front and back of the chest and to the axilla The presence of this murmur may not be detectable in early infancy but becomes accentuated with growth it may develop quite abruptly (Taussig) and the murmur in early years may be classified as systolic and be considered to be a functional one Pulsation is often obvious in the neck and the pulmonary element of the normally split second sound at the base of the heart is accentuated

Quite exceptionally the murmur is entirely systolic if the diagnosis is made with such a murmur it is our practice always to carry out physiological studies by cardiac catheterization for confirmation In the presence of a true Gibson machinery murmur cardiac catheterization is not required for diagnosis

(b) *The size of the heart* This will depend on the size of the shunt Occasionally the enlargement may be gross often it is slight and when the ductus is small absent

(c) *The blood pressure* The pulse pressure is usually wide with a low diastolic pressure in several of our patients it has been zero Characteristically the brachial diastolic pressure is 20–30 mm below the normal and there is usually a low or normal systolic pressure

(d) *The radiological appearances* Typically there is dilatation of the pulmonary artery but this may be equally or more prominent in patients with auricular septal defect both ventricles may be slightly enlarged and radiological screening shows increased hilar dance which again however is best seen in examples of auricular septal defect The enlarged pulmonary artery seen in mitral stenosis only shows feeble pulsation

Characteristically the pulmonary artery shadows in the lung parenchyma are increased (Fig 16 2) It is important to remember that characteristic radiological appearances are not invariably present and the enlargement of the pulmonary artery may not be marked (Fig 16·4)

If angiocardiographs are done (and this is rarely necessary) a bulge in the aortic shadow at the site of the aortic infiltration of the ductus may be seen in the left oblique position

(e) *The electrocardiograph* The electrocardiograph usually shows slight left axis deviation If there is a real right axis deviation an uncomplicated patent ductus can be excluded These findings are modified by the onset of heart failure when T wave inversion may be an important feature

Differential diagnosis

If the typical murmur is audible and the radiological appearances include an enlarged pulmonary artery and increased lung vascularity the diagnosis is made easily The differential diagnosis includes, the maladie de Roger (ventricular septal defect), atrial septal defect, and aorto-pulmonary septal defect or perforation of an aortic sinus into the pulmonary artery

Ventricular septal defect. The diagnosis of ventricular septal defect should not cause difficulty as this provides a harsh systolic murmur best heard in the third and fourth left interspace very close to the sternum, often accompanied by a thrill The patient is not cyanosed, as the shunt is from left to right and the heart does not enlarge In the usual defect the radiological examination of the heart is often normal but may disclose a globular shape and in the instances of a high septal defect there may be pulmonary congestion with visible pulsation on radiological screening It is in this latter group that an erroneous diagnosis of patent ductus may be made if reliance is placed only on the X-ray screening The stethoscope will detect a systolic murmur with no diastolic element



FIG 16 4—A large heart in a boy of 11 years who had infective pulmonary arteritis At post-mortem the only lesion apart from infection of the pulmonary artery was a patent ductus arteriosus

Auricular septal defect. To the thoracic surgeon this condition is of the greatest importance in the differential diagnosis In our series of operations for patent ductus arteriosus a patent ductus has been ligated when there was a known auricular septal defect

the operation was indicated for the relief of gross pulmonary congestion the cause of severe symptoms The operation altered the pre-operative character of the murmur and led to a rise in diastolic pressure and there were no untoward effects there was a marked decrease of the pulmonary plethora The thrill of a septal defect was felt while the thorax was open and a systolic murmur persisted. In another child the thorax was opened on an erroneous pre-operative diagnosis and no patent ductus was present the clinical condition remained unaltered. Apart from an associated patent ductus the wrong diagnosis will not be made except in cases in which an attempt is made to diagnose a patent ductus in the absence of a continuous murmur The diagnosis of a patent ductus on the basis of a murmur limited to systole is rash (Taussig) In both diseases the heart may be enlarged with a prominent pulmonary artery and increased pulsation in the pulmonary arteries on screening The essential differentiation is that a murmur entirely systolic in character is heard over the pulmonary area in the auricular septal defect The differentiation can be made by physiological studies based on cardiac catheterization results

It is of interest to remember that children with septal defects often have repeated attacks of lung congestion and infection This was so in one of the children on whom I ligated a patent ductus in the presence of a known septal defect In this particular child there was also a complete absence of the parietal pericardium over the left half of the base of the heart

Although the shunt in atrial septal defects is essentially a left-to-right one not associated with cyanosis hypertrophy of the right heart due to pulmonary hypertension or pneumonic damage of the lungs may reverse the flow and cyanosis develops The actual defect may be a large patent foramen ovale or a true defect or even complete absence of the septum It is a serious lesion clinically associated with repeated lung infections it is a common defect and the need for its differential diagnosis from the patent ductus arteriosus has been indicated It produces a systolic murmur heard at the base of the heart but this murmur does not run on into diastole as in the one associated with the patent ductus The superior vena cava and the right auricle are enlarged and before cyanosis has developed samples of blood taken from a cardiac catheter will reveal a higher oxygen content in the auricular blood than in that from the superior vena cava The cardiac catheterization findings are discussed in Chapter 15 The unreliability of angiocardiography has been indicated in Chapter 14

The clinical features of atrial septal defect In the auricular septal defects the right auricle and the pulmonary arteries are enlarged and the aorta usually small the left to-right shunt may lead to delayed growth and retarded development there may be slight cyanosis becoming severe in the developed heart failure stages The blood pressure is low the heart enlarged and there is a systolic murmur perhaps with a thrill in the pulmonary area and auricular fibrillation may follow

With some atrial septal defects may be associated mitral stenosis with hypertrophy of the right auricle and ventricle The radiograph shows a large pulmonary artery and this is the only feature that might cause confusion in diagnosing it from patent ductus arteriosus The oblique view of the heart demonstrates the large left auricle a condition not seen in patent ductus arteriosus

Treatment of patent ductus arteriosus

Whether the ductus can be so smoothly ligated as to prevent sub acute bacterial endocarditis remains to be determined If this is possible and operative risk can be reduced

to a minimum, the time may come when every patient with an isolated patent ductus arteriosus should receive the benefit of surgical ligation" (Taussig, 1947).

The surgical bias in favour of operative closure of a patent ductus depends just as much on the potential dangers of a shunt and of continued pulmonary hypertension as the threat of bacterial endocarditis Since the shunt may be between 20 and 70 per cent of the total output of the left ventricle the strain on both ventricles may be considerable and the heart will tend to enlarge. The degree of the shunt is often indicated by the low diastolic blood pressure As the risk of operation is low the prevention of the complication of heart failure or of infection should be sought surgically and before the pulmonary hypertension has become irreversible The mortality rate of surgical closure of the ductus is probably from 1 to 2 per cent between the ages of 4 to 14 Although patients with the condition are advised to lead a normal life, this advice is often accepted with doubt by many and anxiety usually persists, especially when the prognosis has been guarded; at consultation the physician has to explain the possible risks of infection and of later heart failure Most of the patients referred to a thoracic surgeon have not in fact led normal lives and restrictions on activities have been imposed in a large number by the parents For these reasons it is becoming increasingly obvious that most patients with a persistent patent ductus will be operated upon It is certain that operations performed in early adult life because symptoms have developed are a formidable surgical problem and the results not so good as after ligation in early childhood Gross (1947), the leading exponent of this operation, says that he is reluctant to operate on older patients when the operation is more difficult and the condition of the patient bad because of the developed complications When the pulmonary arterial pressure exceeds that of the systemic circulation as the result of long-standing pulmonary hypertension ligation of the ductus would produce a failure of the right heart

My own belief is that a patent ductus should be operated on if seen between the ages of 3 and 10 In 100 operations for patent ductus arteriosus there have been three deaths all these were in patients who had had infective endocarditis as a complication.

The more exact indications for operation include obvious cardiac enlargement, the early signs of cardiac failure, repeated attacks of lung congestion (Fig 16 5), stunting of growth and associated bacterial endocarditis (after antibiotic therapy has checked the infection) Early fatigue after exercise is an indication and these patients invariably have a low diastolic pressure An associated auricular defect with marked pulmonary plethora is no contra-indication and a notable decrease in pulmonary symptoms often follows ligation of the ductus which decreases the size of the left-to-right shunt

Cyanosis due to an associated pulmonic stenosis is an obvious contra-indication to surgical closure The ductus normally should not be tied in early infancy as the diagnosis at this stage is not always easy and the duct may close spontaneously, though I have no personal evidence of this happening after the age of one year Occasionally ligation is necessary before the age of one if the heart is obviously enlarging and the pulmonary congestion is the source of severe symptoms

The ligation of the duct at the ages of 3 to 7 is easier than later The lymphatic and areolar tissue around the patent channel is less well developed and the dissection of the planes simple, the pulmonary artery is not much enlarged and the space between it and the aorta is relatively greater Ligation of the ductus in older patients with severe pulmonary hypertension and a reversal of the flow from pulmonary artery to aorta is highly dangerous and may be fatal because of the sudden failure of the right ventricle Patients should not be allowed to progress to this serious state Children between the ages of 4 and 7





(a) (b)

Fig. 16·5

(a) Radiograph of the chest of a child of 5 years.

The gross lung congestion was associated with severe symptoms, the child being in hospital on many occasions for bronchitis with dyspnoea. A large ductus was present at operation.

(b) Radiograph taken 18 months after the ductus had been ligated.

The symptoms had disappeared.





(a) (b)

Fig. 16·6.—Patent ductus arteriosus.

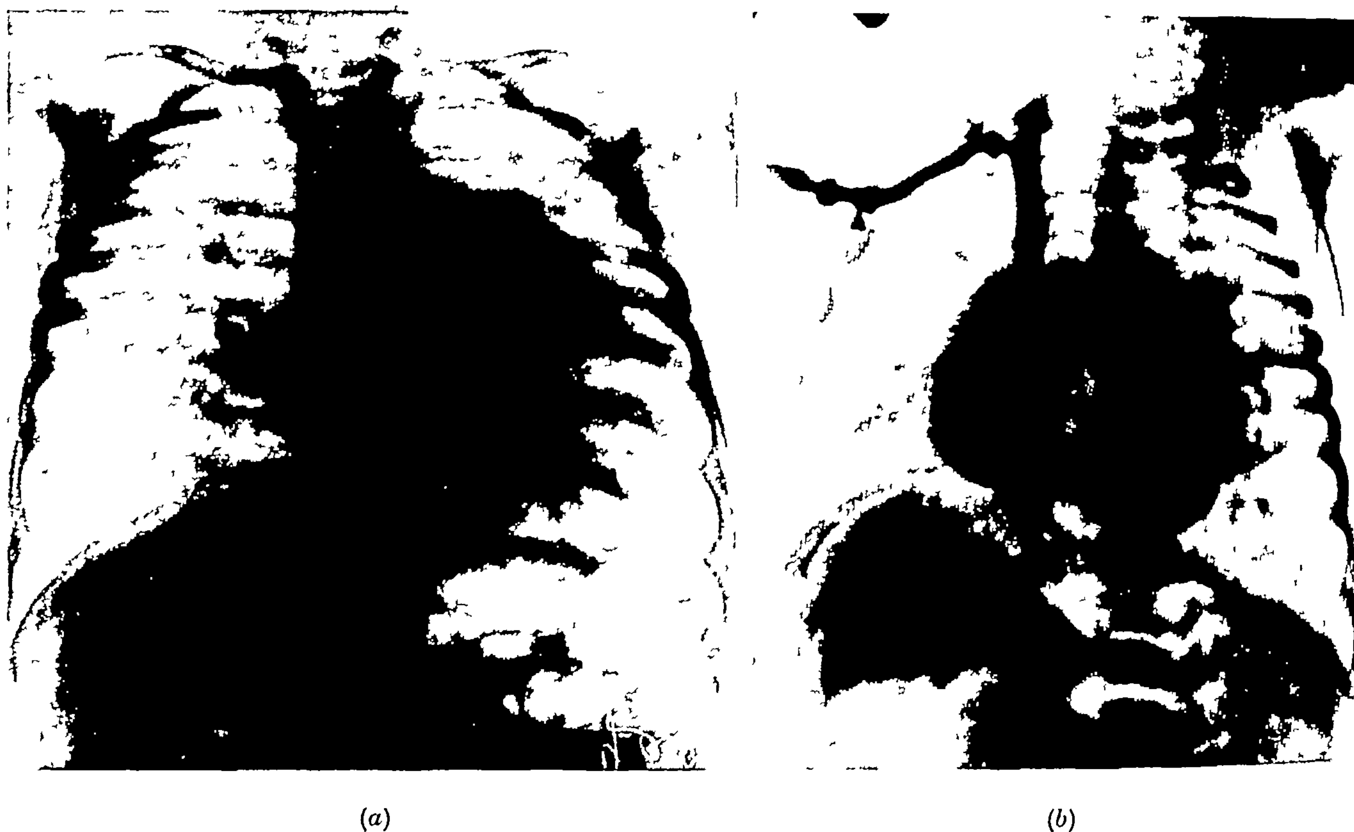
(a) Before ligation.

There is gross pulmonary plethora. This child of 6 had repeated respiratory infections necessitating several admissions to hospital.

(b) A month after ligation of the ductus.

There is obvious decrease in the pulmonary congestion.

stand the operation of thoracotomy with very little disturbance, if the operation is carried out early the parents can be assured of the normality of the heart and the psychological



(a) (b)

FIG 16 7—Patent ductus arteriosus in a child of 12 months who was extremely dyspnoeic and cyanosed when crying The pre operative diagnosis (which was confirmed) made by Dr Clifford Parsons and Dr R Astley was that of a large patent ductus arteriosus with great dilatation of the left ventricle

(a) Radiograph showing the large size of the heart and gross pulmonary plethora

(b) Angio-cardiogram Left oblique view showing the great enlargement of the left ventricle

disadvantages to a child considered to have "a bad heart" can be eliminated and a full normal life encouraged and obtained. Blalock (1951) believes that operation is indicated for all children beyond the age of 2 or 3 who have an obviously patent ductus

The surgical ligation of a patent ductus arteriosus

Pre-operative treatment. The child should be in the ward for a few days before the operation If the operation is to be undertaken for secondary bacterial endocarditis this period will naturally be longer so that intensive penicillin therapy can be given. The pre-operative measures include a careful charting of the blood pressure, especial note being taken of the diastolic reading, a full radiological examination, a blood count and blood grouping and the teaching of breathing exercises by the physiotherapist

The anaesthesia. Because of the tendency of cyclopropane to produce cardiac irregularity during operation, intratracheal gas and oxygen is preferable and is supplemented by pentothal and curare or allied muscle relaxant substitutes the preliminary narcosis may be by rectal avertin administered in the ward

The surgical approach. In Great Britain the classical high posterolateral thoracotomy is preferred to the anterior one which is made between the second and third rib with the patient supine, the posterolateral approach made through the bed of the resected

fourth left rib provides a wider exposure of the thorax than the more limited anterior one I employ it routinely *

When the pleura has been opened widely the left lung is held downward by pressure on a moist saline swab and the left side of the mediastinum at once comes into view The essential landmarks are the phrenic nerve in front the vagus more posteriorly and the arch of the aorta above In this area the typical thrill in the enlarged pulmonary artery is felt The mediastinal pleura lateral to the phrenic nerve is held up in a pair of long artery forceps and is divided up and down by long curved scissors the mediastinal flaps so raised are retracted by a series of fine sutures held in light artery forceps the underlying loose areolar tissue is brushed away from the ductus To make a really adequate exposure the upper limit of the incision into the mediastinal pleura is carried well on to the aorta and the superior intercostal vein crossing obliquely at this point frequently requires double ligation and division The phrenic nerve is retracted medially by a small pledglet swab held in a long curved artery forceps When the loose tissue has been cleared well on to the aorta above and down to the pulmonary artery below the adventitia covering the inferior edge of the aortic arch is opened and separated The vagus nerve is easily identified and the recurrent laryngeal nerve seen curving medially and upwards (Fig 16 8) it marks the

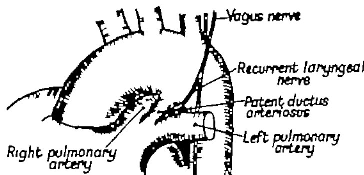


FIG 16·8 —Diagram of the anatomical relations of the ductus arteriosus.

lateral edge of the ductus and is liable to slight bruising while the loose fatty tissue medial to it is being bluntly dissected to expose the extreme left edge of the duct To avoid this the tissue covering the aorta and the ductus is held by a series of fine traction sutures and this carries the nerve away from the ductus The ductus is usually placed obliquely and at first sight may appear to have little or no length as the surrounding tissue is cleared however its true length becomes apparent

The extension of the pericardial sac that overlies the anteromedial surface of the ductus is lifted away with the adventitious tissue as this is dissected downwards The chief difficulty and danger of the exposure of the duct preliminary to ligation is when the posterior wall is being cleared and great caution and deliberation is necessary A large part of the posterior wall of the ductus is seen if the dissection of the surrounding fibro-areolar tissue is carried well down over the left pulmonary artery In my own experience the safest method has been to use a blunt nosed curved forceps slowly introduced medial to the recurrent laryngeal nerve and cautiously passed deep to the ductus at no time must haste or force be used When the curved forceps has been passed clearly round the ductus the ends are separated and any remaining connective tissue can then be more readily divided A double strand of linen thread (size 25) or floss silk is then held down to the

* A good cosmetic result follows the axillary approach favoured by *Denis Browne* if the ductus were accidentally damaged through this approach the problem would be a formidable one As I prefer division to ligation I have not favoured a small thoracotomy incision.

points of the forceps that has been passed beneath the ductus on the end of a long pair of artery forceps and is drawn behind the ductus and divided to provide two ligatures, the ligature on the aortic end is tied first and this is followed by that on the pulmonary end; as soon as the aortic ligature has been tied the thrill that has been palpable throughout the operation stops. The ductus between the two tied ligatures is then transfixed by a finer thread on an eyeless needle, tied once and one end of this ligature is then grasped in a pair of artery forceps previously passed behind the now freed ductus and tied. This is an added precaution against the risk of re-canalization of the channel.

The mediastinal pleura is left unsutured to allow any slight exudate to escape and the chest is closed in layers in the usual way without drainage, the anaesthetist re-inflating the lung which should fill the pleural cavity as the last suture closes the open pneumothorax.

The post-operative progress. This is usually uneventful; any sign of post-operative cyanosis calls for immediate oxygen therapy but this is rarely required. The pulse rate may be raised for 48 hours but then subsides; in older patients the tachycardia may be very evident. The diastolic pressure will have risen to a normal figure. In our series effusions have not been a problem and normally no aspiration has been needed; as a routine a radiograph is taken by the portable machine on the day after operation to exclude or confirm the presence of atelectasis or of post-operative effusions. The patients are usually up on the fourth or fifth day. They should not return to full activity for four weeks, but after that a sensible return to a normal life, free from restrictions, is encouraged.

In the course of months the decrease in the lung congestion is obvious; usually the convex swelling produced by the full pulmonary artery decreases though not invariably; careful measurements show that the enlargement of the heart returns to normal in most instances.

The question of division of the ductus

In the early days of ligation re-canalization of some channels with a return of a machinery murmur may have been due to an understandable caution in the degree of force applied to the actual tying of the ligature, to the employment of suture material so thick (e.g. tape) that it failed to occlude firmly the ductus and to the use of one tie only. If thread or floss silk is used and a transfixion suture placed between the two main ligatures, the risk of re-canalization would seem to be unlikely. In a personal series of 72 ligations three patients re-canalized; the channels were broad in all. Blalock (1951) is able to state that after interruption of the ductus by his multiple suture technique in approximately 300 patients there has been only one known example of re-canalization.

Such authorities, however, as Gross and Crafoord advocate complete division. Gross always divides the ductus and Crafoord does so in a very short broad ductus. Gross has elaborated a beautiful technique; but many surgeons have not adopted this measure though it is impossible to argue against its soundness and effectiveness as practised by its originator, especially if the critic has seen Gross carry out this operation.

In my own practice I now divide the ductus; in 72 consecutive operations in which the ductus was ligated a follow-up revealed that three had re-opened. It is fair to say that one of these was an infected case and the other two were quite exceptionally broad ones. In the last patient of the ligation series, serious haemorrhage followed the tying of the ligature on the aortic end of the channel and after great difficulty the ductus was clamped, divided and sutured after temporary occlusion of the aorta. These experiences led me to prefer Gross's method of division for simple ligation. It is not a comparatively simple operation

like ligation and should only be done by surgeons who have a clear-cut plan of action before they operate

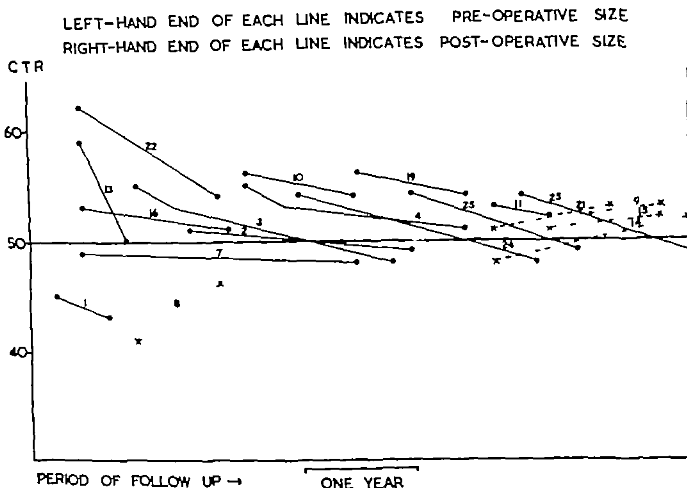


FIG 16·9 —Patent ductus arteriosus. Heart sizes before and after operation in 10 patients.

Each line represents one patient. The left-hand end indicates the heart size immediately before operation, as measured by the cardio-thoracic ratio (C.T.R.). The right-hand end of each line shows the post-operative heart size at a period after operation indicated by the length of the line

The operation of ductus division

The ductus is isolated as described above in the operation of ligation. The artery forceps placed behind the ductus is held in place by an assistant while a thorough dissection of the periductal tissue is made Much fibro-areolar tissue is divided little by little to leave a completely isolated ductus which steadily becomes longer as the dissection proceeds The commencement of the left pulmonary artery is cleared this step helps in increasing the space between the aorta and the main pulmonary trunk as the freeing of tissue anywhere in the confined space of the operative area helps greatly the removal of adventitious tissue proceeds equally thoroughly over the aortic and the pulmonary artery ends of the ductus The pericardial lappet which overlies the ductus is dissected free without opening into the sac it is best retracted after its full liberation, by fine interrupted sutures held in light artery forceps to which traction is applied

The right side of the ductus must be cleared scrupulously and the space between the under surface of the aortic arch and the superior one of the pulmonary trunk adequately exposed. This dissection should never be hurried or skimped

Gross then places four thin bladed artery forceps across the ductus and divides between the second and third ones these two clamps are then removed and the fringe of tissue so

uncovered on each end is sutured Two clamps placed on the aortic and pulmonary end including part of the wall of the great vessels can, however, be used, the clamps devised by Potts are excellent for this purpose If two clamps only are used the division between them must be made with meticulous care to leave a large enough fringe on each side to accept the suture.

The suture material is fine silk (0000 or 00000) mounted on an eyeless arterial needle A continuous suture is placed through the ductal tissue distal to each clamp, one layer will suffice though it can be started at one end and brought back to that point by a returning line of suture (I do not use a returning suture) Each bite of the needle is very close to the one on each side of it It is better to do the pulmonary end first as this rarely bleeds when the clamp is removed, whereas a little smart bleeding may occur from the aortic end When the suture of the pulmonary end has been completed the clamp is removed and a small pack of gauze, oxycel or fibrin foam is placed on the suture line at once and maintained there by steady pressure for five minutes At the end of this procedure it is quite exceptional to see even the faintest trace of bleeding

The aortic end is dealt with similarly, here, as soon as the clamp has been removed, it is not unusual to see one or more jets of blood under pressure squirt from a suture hole Before this becomes troublesome a pack is quickly placed on the suture line and kept firmly in place for five minutes Occasionally an additional interrupted suture or two needs to be placed, *but no attempt to do this should be made until firm pressure has been given* an adequate trial, well beyond the limit of five minutes

Fibrin foam, oxycel or crushed muscle can be placed on both ends before the chest is closed

Before a reasonable experience of this operation of division has been gained it is wise to clear the aorta of adventitious tissue proximal to the ductus so that a temporary clamp or a Potts' clamp as used for aortic-pulmonary anastomosis can be applied if severe bleeding should follow the suturing of the aortic end of the ductus

Special considerations in infected patent ductus

By the thorough use of parenteral antibiotics, bacterial endocarditis, which involves chiefly the pulmonary artery, can be sterilized it is important to remember that surgery before the era of penicillin was able to provide a cure (Tubbs and Keele, 1940) It is therefore clear that after parenteral antibiotic therapy has cured the infection, operation should be practised to avoid the risk of recurrence of the illness Quite exceptionally an infection may arise that will prove to be insensitive to any known antibiotic and then immediate ligation or division will be required to save life

A superimposed infection causes symptoms at first less marked than those of bacterial endocarditis in valvular disease, whether acquired or congenital Malaise, early fatigue, irritability, anorexia, fever with rigors and cough may be present but sometimes the only feature is an unexplained pyrexia associated with a typical Gibson murmur Distant emboli may cause haemoptysis, petechiae and blood cells in the urine The blood culture is not always positive as the dislodged bacterial emboli may not pass beyond the lung parenchyma Pulmonary emboli may be an early cause of haemoptysis, which may also follow the development of mycotic aneurysms in the pulmonary arterial system Areas of lung infarction may be detected on the radiograph Although the endocarditis spreads well beyond the ductus its ligation checks the process and the blood culture becomes negative

A full course of systemic penicillin or aureomycin should be given and this will often lead to great clinical improvement, the blood culture becoming negative Too long a delay

before ligating the ductus is unwise because the operation will prevent that forceful blood current with strong eddies which produces the fibrin on which the vegetations grow

The operative closure of the ductus is difficult in these patients if there is inflammatory matting of the periductal tissue and the isolation and ligation of the duct must be carried out with the utmost operative deliberation, as the wall of the pulmonary artery may be friable as the result of the arteritis The ductus itself may become the site of a fusiform or saccular aneurysm

Aortic stenosis

Coarctation of the aorta

Stenotic and atretic lesions of the aortic arch are surprisingly common (Brown 1939 1950) and provide many different varieties some not compatible with life In distinction to other acyanotic lesions they are commoner in boys than girls The surgical interest in aortic stenosis devolves largely on the stenotic defect seen at or beyond the area where the ductus arteriosus leaves the great vessel (the adult type) narrowing may be present at the aortic valve itself or proximal to the cusps (sub aortic stenosis) The infantile type (Bonnet 1903) is really a long narrowing of the aortic isthmus In most examples of coarctation of the aorta recognized clinically the narrowed or obliterated segment is distal to the origin of the left subclavian artery

Most exceptionally atresia may be present in the thoracic or abdominal aorta the ductus arteriosus may be patent as an associated defect (10 per cent) and the aortic valve

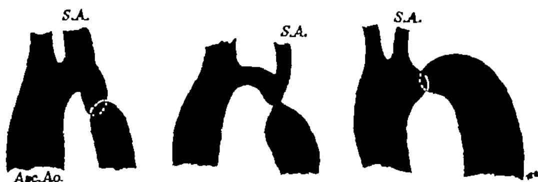


FIG 10-10 —Types of coarctation as shown by angiocardiography (after Salen and Wiklund)
Left—commonest type.
Centre—commonest variation.
Right—infrequent variation.

may have only two cusps (22 per cent of cases Abbott 1936) The aorta is often dilated and thinner beyond the coarcted area with hypertrophy and thickening above it the area of stenosis may be sclerotic or calcified and vegetation of the type seen in endocarditis may develop Great dilatation of the aortic intercostal vessels below the atresia enables a reasonable collateral circulation to be achieved for the body below the obstruction These vessels are tortuous and where they communicate with the arteries of the back they form large channels which erode the ribs and give the characteristic rib notching These abnormally large tortuous vessels may be felt over the upper part of the body especially in the scapular area and in the intercostal spaces Where these dilated vessels enter the aorta aneurysms may arise even at an early age

Inside the narrowed area of the coarctation is a diaphragm which usually has a tiny opening in its centre often smaller than a pin head both above and below this area is an area of fibrosis with no evidence of an arterial media In addition to this lack of a true

middle coat is a firm adherence of the stenosed area to the surrounding tissue from which at operation it has to be freed by sharp dissection especially in the area close to the obliterated or open ductus arteriosus



FIG 16 11 —Excised segment of coarcted aorta seen from below

Note the small crescentic slit in the diaphragm of the intima Resected from a girl of 7 years with a pre-operative blood pressure of 190/120 6 months after aortic anastomosis the pressure was 120/80

The clinical features. The extent and size of complicating side effects such as hypertension and cardiac enlargement govern the presence or absence of symptoms Many young patients are now being diagnosed because of a full cardio-vascular examination after a basal systolic murmur has been heard in a routine inspection and since scepticism has arisen about the diagnosis of functional systolic murmurs If hypertension and cardiac failure have developed, severe symptoms of headache, dyspnoea, cardiac pain and exertional fatigue may follow In the symptomless group, the diagnosis is easily made if the routine of examining the femoral pulses and taking the blood pressures in both upper and lower limbs is followed, as differences in these two areas are the characteristic feature

"Coarctation of the aorta still passes unrecognized—it will continue to be missed if a striking collateral circulation is always expected to be self-evident It will be diagnosed if the femoral pulse is felt for and the blood pressure taken in the legs in every case with high blood pressure or with basal systolic or diastolic murmurs, or with wide pulsation in the neck when these are without an obvious cause" (Campbell and Suzman, 1947–48)

The blood pressure in the upper limbs, head and neck is usually raised to a degree of hypertension (150–220 systolic) with a low blood pressure in the lower extremities and the heart will be enlarged

These clinical features, together with a systolic thrill and murmur over the base of the heart and the detection by sight and palpation of the prominent heart and collateral vessels on the chest wall, especially in the region of the scapula and the anterolateral part of the chest, make the diagnosis certain Further confirmation comes from a typical radiological appearance of "rib notching" on the inferior surfaces of the posterior portions of the ribs due to atrophy from the continued pressure of enlarged pulsating branches of the intercostal arteries The notching is not present in the very young or when there is a patent ductus arteriosus (Evans, 1933) The aortic knuckle shadow is absent on the radiograph On screening the findings depend on the age of the patient and the course of the condition, there may be gross hypertrophy and dilatation with vigorous pulsation usually of the ascending aorta

Prognosis. This is perplexing and only its full evaluation can decide the ultimate place of surgical excision Undoubtedly some patients lead a normal life until middle age, but many die at about 30 years of age

Perhaps the profession is mesmerized into optimism by the undoubted survival of a few remarkable and exceptional subjects to the age of 60 or 70, but Crighton Bramwell at the International Conference of Physicians, London, September 1947, reported 13 patients first seen when over 30 and all of them lived to over 50 He suggested that the third decade was the dangerous period and the prognosis is fair if they survive this age In

other series (Reifenstein Levine Gross 1947) 61 per cent out of 104 patients died before the age of 40

The deaths are due to heart failure hypertensive failure which may include cerebral haemorrhage rupture of the aorta with or without associated saccular or dissecting aneurysm (Fig 16 13) or of aneurysmal dilatation of vessels as all the vessels taking part in the vast collateral circulation are subject to this I have seen coronary thrombosis as the cause of death in a boy of 14 Another hazard is that of infective endocarditis which may effect abnormal aortic cusps or the coarctation itself

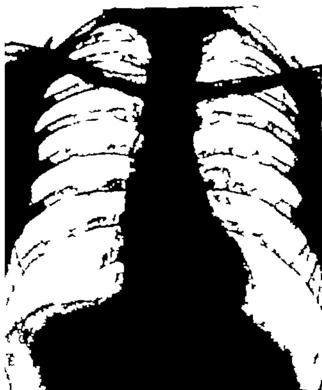




Fig 16-12 Fig 16-13

Fig 16 12 —Radiograph of a patient of 17 years with a coarctation of the aorta.

In spite of blood pressure of 210/140 the heart was not enlarged. There is a characteristic absence of the aortic knuckle and notching of the ribs. At operation when the coarcted area was successfully resected small aneurysmal dilatations were present where the intercostal vessels joined the aorta below the stenosis.

Fig 16-13 —Radiograph of a patient of 42 who six months before collapsed at work after a sudden severe pain in the upper left chest and epigastrium

This had been preceded by exertional dyspnoea for several months Clinically there was obvious cardiac enlargement with a systolic murmur audible in all areas The blood pressure was 230/140 in the right arm and 185/165 in the left arm there were no palpable femoral pulses enlarged pulsating vessels were felt over the chest wall. In addition to the aneurysm seen on the radiograph notching of the ribs is obvious on the right side The patient died suddenly a year after this radiograph was taken.

The indications for surgery If the mortality rate for resection and end to-end anastomosis of the aorta were as low as for the operation in patent ductus arteriosus the decision to advise surgery in all young patients would be fully justified But the mortality rate of operation has now dropped below 10 per cent and this must be offset against the fact that 40 per cent of the patients with this condition die between the ages of 16 and 30 (Blackford 1928) When a healthy child diagnosed because of careful routine examination is presented to a surgeon for an opinion as to the advisability of operation the surgeon is naturally influenced by the grave complications that can develop in the third and fourth decades of life and will usually advise excision and end to-end aortic anastomosis his opinion on patients beyond the age of 20 will be less decided especially as the operation

is technically a great deal more difficult once the heart has enlarged and changes have occurred in the blood vessels My own opinion is that operation should be done in the earlier years of life between the ages of 6 and 12. If a good anastomosis is obtained in young subjects the outlook is excellent, but when performed in patients over the age of 20 the hypertension is not always relieved.

The surgical procedures. Excision of the stenosed segment followed by end-to-end anastomosis (Crafoord, Gross) is undoubtedly superior to the operation of anastomosing the left subclavian artery after its division to the lower aortic segment (Blalock)*, but the latter operation still has a small place, it is helpful for those patients with a long segment of stenosis which after excision left the two aortic ends so widely separated that suture of them was impossible. In such a situation Gross (1949) has obtained brilliant results by sewing in preserved human aortic grafts

Many observations have been made on the results of subclavian aortic anastomosis and without exception they indicate its inferiority as measured by the test of adequate raising of the blood pressure in the lower limbs, for this is usually rather disappointing In one of our patients, after an end-to-end anastomosis had been performed in a boy of 9, a longitudinal tear developed in the lower aortic segment requiring ligation of the aorta, as this developed after a five-hour operation and the general condition was poor the chest was closed, the operation had been done because of severe headache with a hypertension of 190 mm Hg (systolic) In the course of the next few weeks the boy deteriorated, headache and vomiting became continuous and the systolic pressure rose to over 210 The subclavian artery was then anastomosed by end-to-end suture to the lower aortic segment and nine months later he was in excellent health with a blood pressure of 120/80 and symptom free, the pressure in the femoral artery is only 10 mm mercury less than that in the arms The subclavian artery was of the same diameter as that of the aorta below the site of the coarctation This operation, however, should not be employed as the procedure of choice

The operation of excision of the coarctatation and end-to-end aortic anastomosis. A wide posterolateral thoracotomy is made with the patient in the lateral position lying on the right side, the exposure itself is a formidable procedure because of the large arterial channels that exist in the skin and muscles in the line of the incision in the presence of a high blood pressure The incision should be made in small sections at a time and blood transfusion is started at once The whole length of the fifth rib is excised and the back ends of the third and fourth ribs shingled extraperiosteally as a good exposure is essential

The mediastinal pleura over the aortic arch, the area of the coarctation and for at least three inches over the thoracic aorta is divided The coarctation site may show a very obvious coarctation or be the site of a thick mass easily palpable The aorta below the coarctation is thinner than usual and shows poor pulsation The great size of the vessels above the coarctation is obvious, the internal mammary artery being the size of a normal axillary artery The intercostal arteries are all grossly enlarged, thin-walled and tortuous as already mentioned they may show aneurysmal dilatation at the point of entry into the aorta

* It is important to quote Blalock accurately he reserves subclavian-aortic anastomosis for the infantile type of coarctation that is long or the adult type when the proximal or distal segment is hypoplastic for a short distance The whole of the constricted segment is excised and the proximal end of the aorta closed by suture the subclavian artery is rotated down in such a way that it is not kinked and is anastomosed to the distal end of the aorta In three children treated by this method we have had good results in two and a poor result in one

The isolation and division of the upper intercostal arteries below the coarctation is one of the most difficult and tedious parts of this exacting operation no more should be sacrificed than is essential to allow the aorta to be fully mobilized Crafoord frequently does the operation without sacrifice of any using temporary bulldog clamps on them after their meticulous isolation but division of two or three pairs is of little account if a good anastomosis is obtained The adventitia of these and of the bronchial arteries which lie on the medial side should be opened freely before the vessels are encircled and ligated their thinness makes them very liable to rupture They should be tied with silk or linen thread

The aorta is then held up in linen tape to enable the vessel and the constricted area to be elevated and completely freed of surrounding attachment the mobilization of the atretic segment may be difficult in the region of the obliterated ligamentum arteriosum which is divided it may be patent

The left subclavian artery and the aorta between it and the left carotid artery are mobilized with advantage except in patients where there is plenty of room for the application

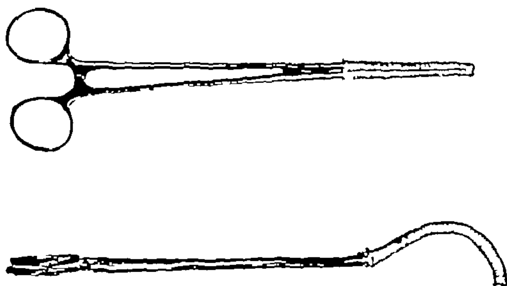


FIG 16-14 —Coarctation clamps (Crafoord type)

of an aortic clamp well above the coarctation If the mobilizations mentioned are executed clamps can be placed across the aorta and the subclavian artery if the segment below the last named artery is very short Whenever possible however occlusion of the subclavian artery should be avoided as its temporary obstruction greatly adds to the burden of the heart beating against an already high peripheral resistance

When the mobilization is complete two aortic clamps of the Crafoord or Potts type are placed above and below the constricted area and held by an experienced assistant The coarcted segment is then excised and an end to-end anastomosis carried out by a continuous suture of 000 silk carried on an eyeless needle The usual vascular suture is employed with each loop lying outside the vessel on the adventitia (Fig 16 15) During this suture the assistant must hold the clamp in such a manner that there is no tension at any stage on the suture line If the operation is done in young children the anastomosis may be made by interrupted sutures as this may allow the new opening to enlarge alongside the natural increase in the size of the patient

The lower clamp is removed first, it is usually accompanied by a slight leak of blood as the pressure within the lumen is not sufficient to tighten up the suture line if bleeding is excessive at any spot an interrupted mattress suture is applied as the upper clamp is slowly removed the anastomosed segment fills with blood and the previous oozing ceases

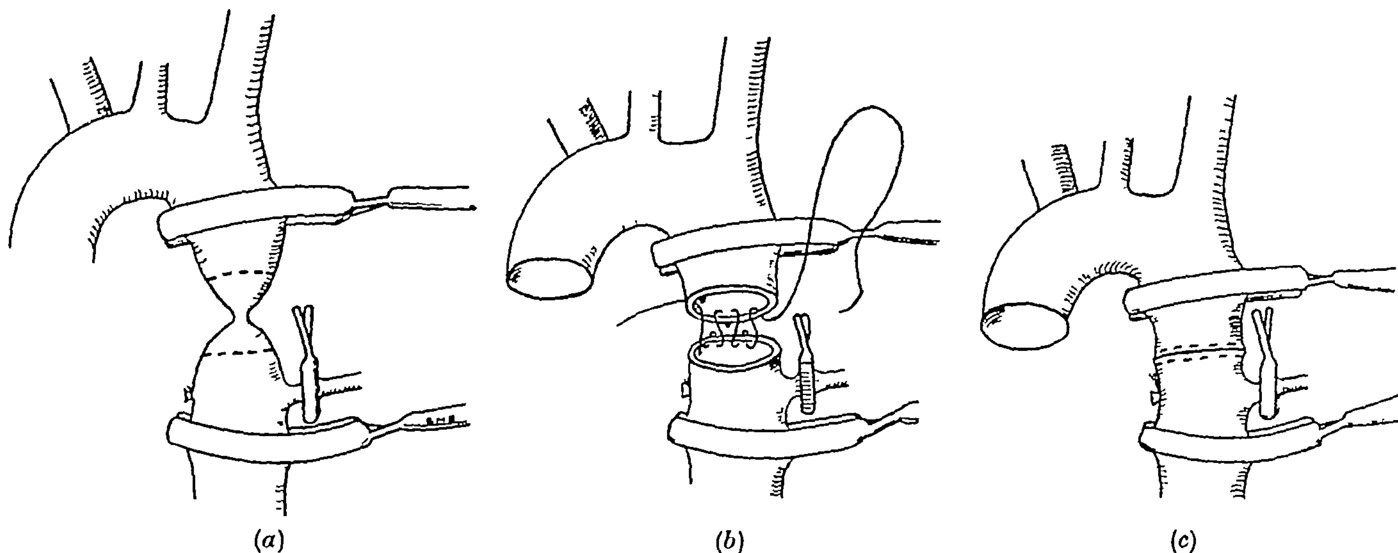


FIG 16 15—Diagrammatic scheme of operative excision of area of coarctation of aorta

(a) The aorta above and below is temporarily occluded by Crafoord's clamps A Crile's clamp has been placed on a large intercostal vessel
(b) The posterior line of aortic suture has been placed so that the loop falls on the adventitia
(c) Shows the aortic suture completed

Gross (1947) advises that the upper clamp should be released very slowly (five minutes) so that there is no sudden release of blood into the lower part of the body leaving sufficient blood pressure in the left ventricle to supply the coronary artery, at the moment of release the blood drip rate should be rapidly increased and the head of the table lowered. The chest is closed in the usual way with temporary intercostal water-sealed drainage.

Abnormalities of the aortic arch and their significance in thoracic surgery

Abnormalities of the aortic arch may be of surgical significance, only the briefest reference can be given here The abnormalities are due to faulty persistence of the embryological aortic arches which in early life unite to form the dorsal and ventral aortae Some of these arches persist in life, e g the third forms the internal carotid artery, the fourth right one persists in part as the innominate and subclavian arteries, that on the left providing part of the aortic arch, the sixth arch providing the pulmonary artery and on the left the ductus arteriosus The remainder of the arches disappear but may show irregular persistence and produce the most bizarre aortic arrangements and many odd combinations have been noted The aorta may be right-sided at first and then pass over to the left side behind the trachea and the oesophagus Persistence of the left part of the aortic system may coexist so that a vascular ring encircling the oesophagus and trachea may be present This ring or the abnormal retro-oesophageal course of a left subclavian artery arising from the right of the aortic arch may cause dysphagia, and in a few recorded examples relief has followed surgical division of certain components of the ring

Dysphagia is rare but usually arises only in the presence of degenerative enlargement of the abnormal vessels in the later years of life The abnormality may also cause dyspnoea from tracheal encirclement and Gross (1945) first relieved this by surgical division of the vascular ring It is important to remember that in performing the operation of Blalock

for congenital cyanotic lesions difficulty may be encountered in finding and exposing the subclavian artery if it is in the retro-oesophageal position These conditions can be diagnosed radiologically

In perhaps 25 per cent of congenital lesions of the tetralogy of Fallot type the aorta may descend on the right side This can be readily demonstrated on radiological screening especially when the oesophagus is outlined by barium (Bedford and Parkinson 1936) To the surgeon this is important when he is deciding upon the approach to be adopted for Blalock's operation and the pre-operative evaluation of which systemic artery will be available for the anastomosis

Gross and Ware (1946) classify aortic arch anomalies as follows

(1) *Right aortic arch*

(*a*) Situs inversus viscerum

(*b*) Right aortic arch without inversion

(i) Anterior type with the arch anterior to the trachea and the descending aorta right-sided

(ii) Posterior type—the arch passes to the left behind the oesophagus and the aorta descends to the right of the normal left-sided position

(*c*) Right aortic arch in which the left subclavian artery arises last from the arch and crosses behind the oesophagus

(*d*) Right aortic arch with no vessel arising from the arch crosses the mid line behind the oesophagus

(*e*) Right aortic arch with a persistent left aortic diverticulum giving origin to the left subclavian artery and the ligamentum arteriosum

(2) *Double aortic arch*

(*a*) One aortic limb patent

(*b*) Both aortic limbs obliterated

(3) *Anomalous right subclavian artery*

This arises from the left side of a normal aortic arch to its distribution on the right side

(4) *Patent ductus arteriosus*

(5) *Coarctation of the aorta*

A right aortic arch represents a persistent right fourth branchial artery The left one normally forms the arch Many variations in the origin and course of vessels arising from a right-sided arch have been noted

Abnormal origin of right subclavian artery

One of the commonest anomalies of the aortic arch is when the right subclavian artery arises from the left side of the arch and proceeds upwards and to the right behind the oesophagus or between the oesophagus and trachea Holzapfel (1899) found the artery behind the oesophagus in 107 cases between the oesophagus and trachea in 6 and in front of the trachea in 6 The vessel usually crosses the mid line of the body at the level of the third dorsal vertebra Often there is a slight aneurysmal dilatation of the subclavian as it leaves the arch In 1794 Bayford reported his case of dysphagia lusoria in a woman who had suffered from dysphagia for years At post mortem examination

the oesophagus was seen to be indented by an abnormal right subclavian artery, but the abnormality may exist without causing any symptoms Gross in 1946 knew of six cases demonstrated radiologically. In four of the children there was no dysphagia, slight dysphagia that remitted in one and in the sixth (a four-month infant) the dysphagia was so severe that the artery had to be divided If the vessel passes in front of the trachea there are usually no symptoms Fortunately division of the first part of a subclavian artery is not likely to impair the blood supply to the right arm. There was no real stridor in Gross's operation case

Of the recorded vascular rings many have been seen in adults with no symptoms, they may cause mild or severe dysphagia, but in infants serious obstruction and early death has been noted (Gross, 1945)

Vascular rings in the mediastinum (double aortic arch)

Gross (1945) was the first surgeon to apply the anatomical knowledge of aortic anomalies to the relief of patients suffering from dyspnoea or dysphagia or both Radiologists for some years have described accurately the anatomy of these anomalies in living patients in many there are no symptoms, but oesophageal and tracheal pressure may arise in early infancy or late middle age In the older patients the onset of symptoms after years of freedom is due to enlargement of the vessels as the result of atheromatous changes and the clinical picture lacks the respiratory embarrassment noted in some infants

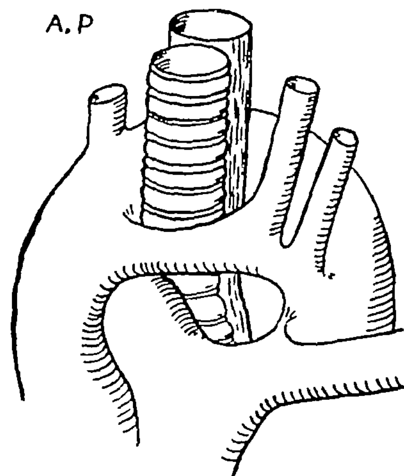


FIG 16 16—Diagram of double aortic arch (after Gross)

(A) The main aortic arch may pass behind the oesophagus instead of in front of the trachea The pulmonary artery is anchored to the distal arch by the patent ductus arteriosus or the ligamentum arteriosum to the left of the oesophagus and trachea

If such a combination produces obstructive symptoms Gross thinks that division of the ductus might relieve them

(B) *Divided or split aortic arch.* In this abnormality the aorta has two limbs, one passing to the left behind the oesophagus with the other proceeding to the left in front of the trachea Both then join to the left of the mediastinum to form the descending aorta, the great vessels may show unusual sites of origin from either limb, and such abnormal arrangements might make division of the arch impossible

Gross's first patient This was a four-month-old infant admitted to hospital 14th October, 1944, because it had wheezed since birth On radiological examination a wide superior mediastinal shadow was noted and thought to be an enlarged thymus which was treated by deep X-ray therapy without improvement A month later the infant was ill with cough, noisy breathing, vomiting and a temperature of 101° Four months later the infant was in hospital again, a hoarse cry and cough severe enough to interfere with feeding were associated with a temperature of 102° and a pneumonic infiltration which improved with chemotherapy though the middle lobe remained collapsed. In May 1945 the infant, a well-developed child, was re-admitted in acute respiratory distress, cyanosed and pyrexial

A barium swallow showed slight narrowing of oesophagus opposite third and fourth thoracic vertebra and a lateral view showed posterior indentation of the oesophagus A mass was seen between the oesophagus and the vertebral column while lipiodol in the trachea disclosed a narrowing of the trachea above its bifurcation

After another respiratory crisis operation was decided upon and through a left anterior thoracotomy the great vessels were visualized

A divided aorta encircled the oesophagus and trachea. The ligamentum arteriosus was divided with only slight relief. As the posterior part of the arch was bigger the anterior part was divided. This at once relieved the trachea and most of the stridor disappeared. To further increase the peri tracheal space Gross then lightly sutured the left common carotid artery to the back of the sternum. The patient made an excellent recovery.

In June 1950 we were fortunate enough to be able to relieve a child with gross stridor and cyanosis who had suffered symptoms very similar to those in Gross's patient. At thoracotomy there was a double aortic arch present, fortunately the smaller part of the ring lay behind the oesophagus and thus was divided with complete relief (d'Abreu, Astley, Parkes 1952).

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CHAPTER 17

CONGENITAL CYANOTIC HEART DISEASE

These patients have cyanosis of a central type, obvious at rest and associated with exertional dyspnoea There is a venous-arterial (right-to-left) shunt, associated in the most important and largest group with a diminished blood flow to the lungs because of obstruction somewhere in the outflow track (the tetralogy of Fallot which represents some 70 to 75 per cent of congenital heart disease with cyanosis) When the defects of the tetralogy heart exist apart from any obstruction to the blood flow to the lung the condition is known as Eisenmenger's complex, since the pressure in the pulmonary artery is high there is no place for any surgical attempt to increase the blood flow to the lungs in this second group in whom cyanosis develops late.

Other causes of cyanosis are tricuspid atresia, pulmonary stenosis with patent foramen ovale or with a reversal of shunt through an atrial septal defect, complete transposition of the great vessels and persistent truncus arteriosus

The reduced exercise tolerance and the cyanosis can be relieved by surgery if the pulmonary blood flow is deficient in addition to the venous-arterial shunt Surgery cannot correct the right-to-left shunts but can augment the blood supply to oligaemic lungs in two different ways The group in which anastomosis of a systemic artery with the pulmonary artery can be of value includes the tetralogy of Fallot, tricuspid atresia and a persistent truncus

Two operative procedures are employed (1) The Blalock-Taussig operation and its modifications (Potts, 1946), which divert a proportion of the unsaturated arterial blood into the lungs by the creation of an artificial ductus arteriosus between the systemic and pulmonary arterial systems (2) The Brock pulmonary valvulotomy or infundibulotomy, which removes the obstruction to the blood flow from right ventricle into the pulmonary artery.

A large venous arterial shunt is a prerequisite of the Blalock-Taussig operation If the pulmonary arterial pressure is not elevated and the creation of an artificial ductus technically possible a successful functional result depends upon the capacity of the left ventricle to meet this additional burden without starvation of the systemic circulation, therefore the septal defect must be of sufficient size and suitably placed to allow blood entry into the systemic circulation from the right side of the heart In the tetralogy of Fallot the transference of blood to the left side of the heart is facilitated by an overriding aorta and the systemic blood flow is not restricted by the presence of pulmonary stenosis and may be greatly augmented by the stimulus of exercise Such cases are suitable for a Blalock-Taussig anastomosis

Pulmonary stenosis may occur as an isolated condition without any septal defect and a closed foramen ovale, the systemic blood flow will be regulated by the severity of the pulmonary obstruction and will be equal in size to the effective pulmonary blood flow and the arterial blood free from venous admixture, will have a normal oxygen saturation In these cases the creation of an artificial ductus will be valueless

Pulmonary stenosis may be associated with a small septal defect of the auricles or a patent foramen ovale which limits the size of the venous arterial shunt and therefore prevents

any substantial increase in the size of the systemic blood flow and here again an artificial ductus will be valueless Pulmonary valvulotomy is the operation of choice in these cases and those with isolated pulmonary valvular stenosis

In the tetralogy of Fallot pulmonary valvulotomy or infundibulotomy is theoretically preferable to a Blalock Taussig anastomosis since it will increase the pulmonary blood flow and relieve the right ventricle whilst the latter operation augments this flow with arterial blood containing a proportion of oxygenated blood which has already perfused the lungs The technical difficulties of resecting an infundibular stenosis must be offset against this obvious advantage

About one-third of the patients with congenital cardiac lesions develop early and severe cyanosis The colour change may develop late in some left to right shunts (e g patent ductus arteriosus interauricular septal defects) when heart failure develops and the shunt becomes reversed Cyanosis as would be expected is most commonly associated with pulmonary stenosis usually with severe associated abnormalities as in the tetralogy of Fallot The cyanosis may be present at birth or develop after some months or years of life

The tetralogy of Fallot

The classical type shows a high interventricular septal defect with the aorta overriding both ventricles hypertrophy of the right ventricle and stenosis or atresia of the pulmonary artery or of its infundibulum The last abnormality is the most important one as far as

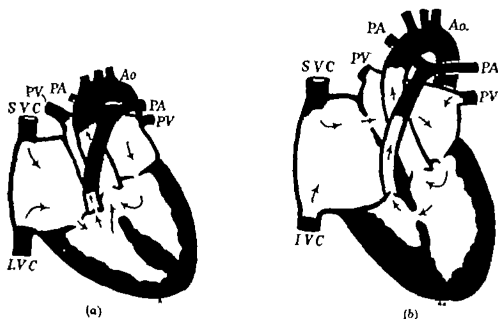


Fig 17 1

(a) Diagram of tetralogy of Fallot

Showing interventricular septal defect overriding aorta, stenosis of pulmonary artery and hypertrophy of right ventricle

(b) Tricuspid atresia with rudimentary right ventricle

A Taussig-Blalock operation is also employed in this condition.

the surgeon is concerned as the surgical aim is to augment an inadequate pulmonary blood flow by anastomosing a systemic artery such as the subclavian or the aorta to the pulmonary artery or by a direct attack on the site of stenosis If the latter operation is employed the pre-operative studies of stenosis must be faultless The differentiation of valvular stenosis from infundibular obstruction is not easy even with the most excellent angiocardiography pictures At the moment of writing there is little doubt that surgical division of a stenosed valve (valvulotomy) is a safer procedure than resection of an infundibular obstruction

Clinical features. Once cyanosis develops (the combined result of an inadequate blood supply to the lungs and the venous-arterial mixture of blood across the septal defect) it becomes progressively severe, it is seen most easily in the tongue, lips, lobes of the ears, and in the clubbed fingers and toes. The infants or children grow slowly, are underweight, and tire easily, they become breathless on exertion, though the exercise tolerance varies considerably according to the severity of the defects The children are often intelligent and of pleasant personality The peculiar habit of squatting is typical of patients with a defective blood flow to the lungs.

Bouts of unconsciousness are common and follow unexpected demands on the inadequate oxygen in the blood stream after attacks of anger or sudden exercise, especially in the

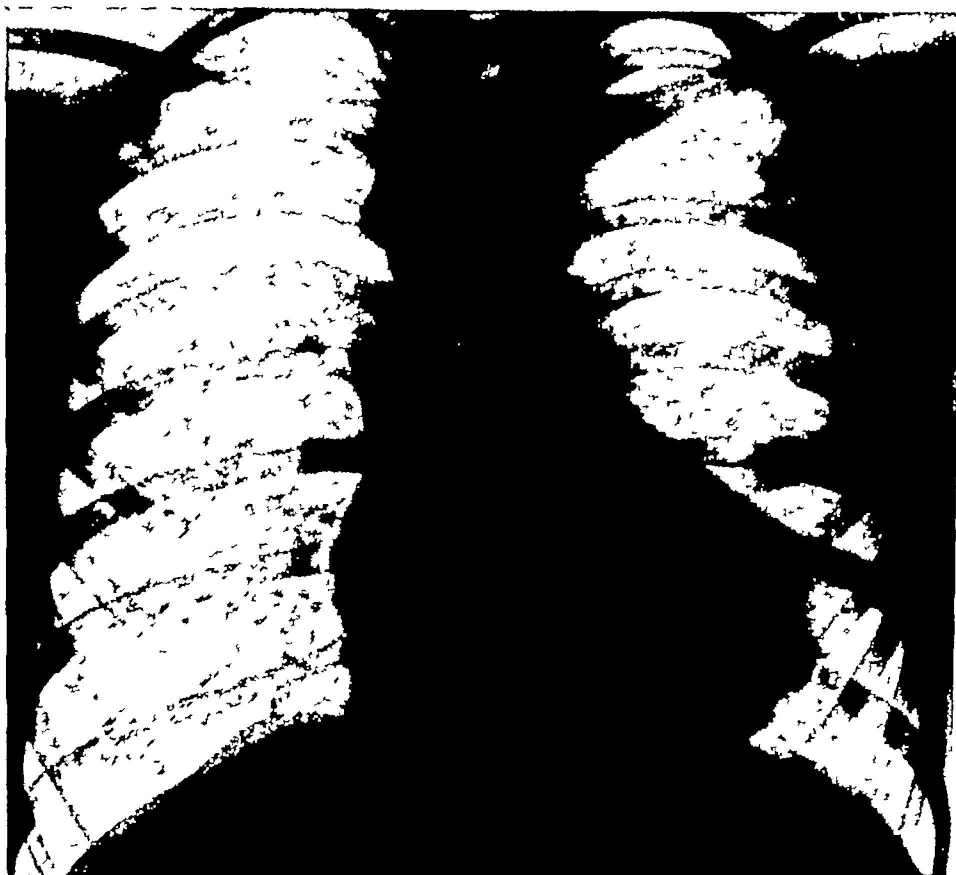


FIG 17 2 —Radiograph of a patient showing the boot shaped heart characteristic of Fallot's tetralogy A left-sided Blalock anastomosis has been done The thoracotomy was performed through the bed of the resected fourth left rib which has partly regenerated

morning As in all congenital cardiac lesions there is an ever-present danger of infective endocarditis which is in no way diminished by surgical treatment The most trivial procedure such as teeth extraction must always be done with antibiotic protection The heart though altered in shape is not usually enlarged and there is a basal systolic murmur, accompanied by a thrill in half the patients, with a clear single second sound

Radiology. The heart is usually boot-shaped, being tilted up to the left because of the hypertrophy of the right ventricle with a concavity in the pulmonary artery area and clear lung fields indicative of a poor blood flow through the pulmonary artery Radiological screening demonstrates hypertrophy of the right ventricle and unusual clearness of the pulmonary window, the area seen in the left anterior-oblique position behind the main

pulmonary artery below the arch of the aorta the pulsations of the pulmonary arteries in the hilum of the lung are slight or absent In 25 per cent of the patients the screening will show the aorta descending on the right side and this can be confirmed by noting that the aortic depression on the oesophagus when barium is swallowed faces to the right and not the left

The electrocardiogram shows a right axis deviation and the physiological adaptation of the blood to a deficient oxygenation is reflected in a high red blood cell count of from 6½ to 10 millions with a proportionate rise in haemoglobin of the normal 100 per cent to 120–180 per cent the oxygen saturation of the arterial blood is low and may be down to 30–50 per cent in severe cases

Confirmation of the diagnosis Since every cyanotic congenital heart patient with pulmonic stenosis and an intracardiac right to left shunt can theoretically be helped by an anastomosis of a systemic artery to the pulmonary artery the essential pre-operative need is to prove that poor pulmonary blood flow exists The clinical features just described usually provide this information of all the investigations the estimation of the presence absence or diminution of the expansile pulsation in the pulmonary artery is a most important fact to be established. In the typical Fallot patient the diagnosis is usually certain after clinical and radiological examination but great assistance in its confirmation can be obtained from angiocardiography and cardiac catheterization (Chapters 14 and 15)

The exact anatomical pattern is shown by angiocardiography and the exact pressure within the pulmonary artery and the outflow tracts of the right ventricle is estimated by the catheter studies

The most important diagnostic differentiation is between Fallot s tetralogy and the Eisenmenger complex

The Eisenmenger complex

In this condition the defects are those of the tetralogy of Fallot with the important and detectable absence of any obstruction to the flow of blood into the lungs The pulmonary artery is large shows expansile pulsation when the chest is screened and a cardiac catheter introduced into the pulmonary artery records a normal or high pressure The cyanosis develops later because the steady rise of pressure in the pulmonary circulation produces such hypertrophy of the right ventricle that more and more venous blood is driven through the ventricular septal defect An anastomosis of a systemic artery to the pulmonary artery will not only fail to improve the condition but may cause pulmonary oedema Physiological studies in such a lesion show typical pictures (Chapter 15)

The value of angiocardiography Screening and cardiac catheterization will establish the diagnosis and provide a pre-operative estimate of the pressure in the pulmonary artery and confirm the presence of or absence of a pulmonary artery but it is of great value to know before operation the state of the aorta and of its branches Anomalies of these are frequent and it is important to know whether there is a suitable subclavian artery on one or other side that is large and long enough for anastomosis to the pulmonary artery Good angiocardiograms will give this information and may save a faulty choice of side for thoracotomy It also has considerable diagnostic value and proves the presence of a right to left shunt and gives an estimate of the amount of blood that passes directly from this shunt into the aorta and of the diminution of flow into the pulmonary artery (See Chapter 14)

Surgical treatment of the tetralogy of Fallot with pulmonic stenosis

In the untreated case the chances of survival to a happy and useful adult life are negligible half the children succumb before the age of 6 or 7 years, one in four is likely to live till 14 and less than one in ten survive to the age of 21 (Campbell, 1950) In addition to the natural mortality rate many of these cyanosed, dyspnoeic children are debarred from most of the normal pleasures of childhood The mortality rate and the morbidity effects of surgery, which necessarily carries hazards, are less than the natural dangers of the untreated patient who has severe dyspnoea on exercise

The age for operation Since many of the children succumb before the age of 7 years there is a strong case for advising operation when the child is 4 or 5 , earlier operation has the disadvantage that the systemic vessel to be used for the increased blood flow to the lungs is not well developed and the size of the anastomosis may be inadequate as the child grows bigger , but if on clinical observations the child appears unlikely to survive and is in fact deteriorating, operation may be done earlier In my own series the youngest child was operated on on his third birthday and the subclavian artery employed for the anastomosis was a large vessel and the result was good If, however, operation is done at a young age, it is better to select the aorta for the anastomosis (Potts' operation)

Choice of operation Three operative procedures are available

(1) The Taussig-Blalock anastomosis of a large systemic vessel to the pulmonary artery, preferably by end-to-side anastomosis, which increases the blood flow to both lungs The ideal vessel is the subclavian artery, as the use of the innominate or carotid vessels lays the polycythaemic child open to the grave danger of cerebral thrombosis The choice of the left or right subclavian artery will be discussed later

(2) The Potts modification of Blalock's operation This involves a side-to-side anastomosis of the aorta to the pulmonary artery An ingenious clamp allows the aorta to be clamped in such a way that blood still flows through the main channel, leaving the

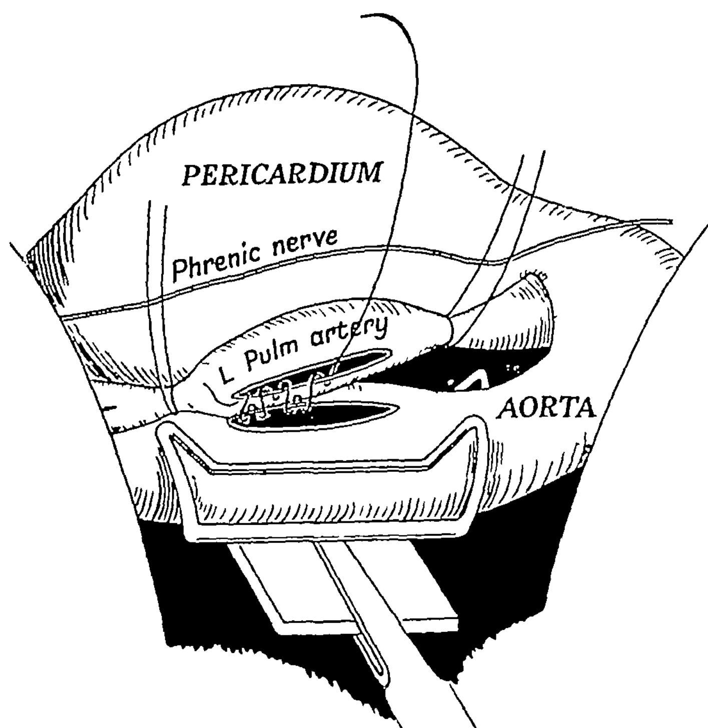


FIG 17 3 —Potts' operation.

The left pulmonary artery has been temporarily occluded by two stout ligatures which encircle the vessel twice without being tied The aorta has been partially occluded by Potts' clamp and the first layer of the anastomosis is partly completed

segment selected for the anastomosis distal to the clamp The method has the great advantage that it can be used when the subclavian vessel is too small or too short to provide a good anastomosis There is however a tendency to make the opening too large and this may place a great strain on the left ventricle if too great a volume of blood flows into the pulmonary circulation The aortic incision should be a quarter to three-eighths inch in length according to the stature of the child In addition to this risk the hazards to the aorta are materially greater than those to the subclavian artery

(3) *Brock's operation* This logical operation aims to fulfil the general surgical principle that obstructive lesions whenever possible should be relieved at the site of stenosis and is free from the objection levelled against the Blalock procedure that it increases the burden of a deranged heart by creating an arterio venous fistula distal to it Brock has devised two procedures one being a pulmonary valvulotomy and the other a resection of the hypertrophied muscular bands in the infundibulum these are discussed later

The Blalock-Taussig operation

Selection of the side and type of exposure In his first large series of patients Blalock advised operating through the side of the chest opposite to the aortic arch because the divided subclavian artery coming off the innominate trunk can be turned down to the pulmonary vessel in a curve which appears far more efficient than the angled appearance of the divided left subclavian artery which has to be turned down from the aortic arch In many patients however the use of the subclavian artery that arises directly from the aorta is fully efficient in spite of the apparent kink noted at the end of the operation and many surgeons select the left side provided the pre-operative estimate (made largely on angiocardiography) has demonstrated a reasonably large vessel on that side The advantage of the left side is that there is no troublesome superior vena cava in the way of the mediastinal dissection and that the left-sided subclavian vessel is longer than its fellow on the right In about 25 per cent of these patients the aorta descends on the right side (as proved by pre-operative radiology) and then the perfect condition for a left thoracotomy exists because the angle formed by the downwards placed subclavian artery is less acute than when it arises directly from the aorta

The thoracotomy may be anterolateral or posterolateral and it is presumptuous to favour the latter when Blalock is so clearly in favour of the other one Many however prefer the posterolateral thoracotomy because of the better exposure and access that it gives Its roominess is an advantage and it can be executed quickly and comfortably because of the better exposure the easier dissection of the subclavian artery and the suture of the anastomosis is easier Its supposed disadvantage of placing a greater strain on the underlying lung and of allowing the mediastinum to fall over to that side is abolished by careful use of controlled respiration with adequate use of intratracheal lung inflation It does however interfere more with the collateral circulation of the upper limb which is to be deprived of its subclavian artery because some of the natural anastomosis of vessels around the shoulder-girdle is destroyed

Pre-operative measures The child should be long enough in the surgical ward to have become accustomed to the nursing staff and to have received training in the physiotherapeutic measures which will play an important part in the post-operative phases part of the day is spent in an oxygen tent to avoid its being a frightening enclosure post-operatively A high fluid intake must be maintained because of the great danger of dehydration in a polycythaemic child and as a measure of training for the necessary post-operative forcing of fluids Parenteral penicillin is commenced on the day before operation

Anaesthesia The tolerance of these cardio-respiratory cripples to anaesthesia is astonishing , this is not to say that the anaesthetic problems are not difficult and complex and at any stage disasters subject to a deepening of the prevailing anoxaemia or to cardiac irregularity may arise and the anaesthetist carries a continuous burden During the operation the surgeon requires the quietness of respiration that can only be obtained by controlled respiration , in infants this is not to be achieved by hyperventilation and carbon dioxide absorption unless a dangerous depth of anaesthesia is reached For this reason curare or muscle relaxants are used to supplement the action of pentothal or ether and oxygen , the curare dosage must be so estimated that rapid recovery ensues and that at the close of the operation the cough and the pharyngeal reflexes are present

Cyclopropane has the disadvantage that it may produce cardiac irregularities, most surgeons and anaesthetists prefer a mixture of ether and oxygen Nitrous oxide and oxygen is unpopular as it may produce a dangerous anoxic anoxaemia and I know of one death when it was used for a dental extraction of one tooth in a cyanotic child When the child has been gradually anaesthetized under a pre-operative cover of barbiturate narcosis an intratracheal tube is passed , in spite of certain opposition to intubation in these children, greater safety is ensured by its application because it enables prompt clearing of the tracheo-bronchial tree to be effected by suction, as bronchial secretions may have a serious effect on the oxygen absorption by the lungs The larynx is anaesthetized by a spray of 2 per cent Butyn before the tube is passed An extraordinary feature often noted is that the colour of these patients improves as soon as a satisfactory anaesthetic relaxation has been achieved the reason for this is probably the decreased call for oxygen by the tissues, but the lungs of these patients probably take up more oxygen even though oxygen uptake theoretically is already at its highest

A slow saline intravenous drip is maintained throughout the operation to decrease the risks of dehydration, as these polycythaemic patients are naturally liable to thrombosis. Blood transfusion is not employed but it must be available in case of a severe haemorrhage through a technical accident

The operation With the patient in the classical lateral position the fourth rib is fully exposed and resected sub-periosteally from its angle to the costal cartilage When the pleura is opened the condition may deteriorate temporarily but this is not noticeable if the lung on that side is not allowed by the anaesthetist to collapse , it is better to displace a partially inflated lung throughout the operation by a moist saline swab to which sufficient retraction is applied through a light metal gauze mesh retractor enabling the hilum of lung and the superior mediastinum to be visualized fully, than to allow it to collapse

Exposure of the pulmonary artery This may be easy or difficult depending on the absence or presence of collateral veins in its sheath The sheath is opened thoroughly from the pericardial reflection medially and well into the lung laterally so that the two major branches of the vessel are clearly seen The adventitious tissue must be throughly separated from the artery by a mixture of blunt and scissor dissection , this is greatly facilitated by placing umbilical tape round the vessel as soon as an adequate space has been secured for its passage , elevation of the tape held in forceps enables the posterior wall of the vessel to be cleared A long length of the vessel and its first two branches are freed completely from all fascial investments , a rubber-shod Blalock clamp is then placed on the proximal side of the artery and the effect of its closure noted If the patient is not unduly disturbed it is clear that the pulmonary artery on the other side is carrying sufficient blood to enable a satisfactory respiratory exchange of gases to be maintained the clamp is then loosened and attention paid to the systemic artery to be selected for the anastomosis

Exposure of the systemic artery In the absence of gross abnormalities of the distribution of the aortic branches the exposure and clearing of the subclavian artery is an easy procedure The mediastinal pleura over it is divided freely from the level of the aorta up to the division of the artery a small vein usually crosses the vessel just before it divides into branches and this is doubly ligated and divided If the aorta is right-sided the recurrent laryngeal nerve is isolated carefully as it comes off the vagus nerve to pass round the origin of the subclavian artery as it leaves the innominate trunk. When the subclavian artery and the innominate artery have been cleared a bulldog artery clamp is placed on the vessel near its aortic origin before it is divided and its cut end is brought out underneath the recurrent laryngeal nerve if the arch is right-sided both sides of the bulldog clamp should be held by two ligatures tied firmly to prevent any danger of slipping

The subclavian artery is liberated completely from its bed up to its branches some times these branches are given off very low they are carefully isolated doubly ligated and divided An early decision as to the suitability of the subclavian artery for anastomosis

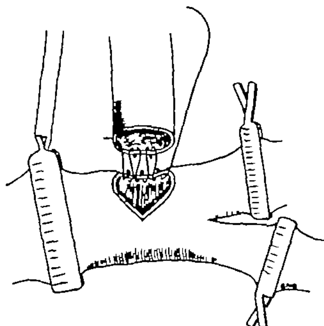


FIG 1 4 —Diagram of a Blalock anastomosis of the left subclavian artery to the side of the left pulmonary artery indicating the type of suture used with the loop lying on the adventitia.

must be made for if it is too short or narrow Potts operation is substituted Usually the subclavian is divided at the point where the first two vessels are given off after these have been tied and a clamp placed close to the aortic origin of the subclavian artery at times it is useful to divide the branches after they have left the main trunk and the double barrelled end so left may have its bridge divided to leave a trumpet-like opening which enables a bigger surface to be sutured to the pulmonary artery ostium

The anastomosis Before this difficult stage of the operation is commenced the anaesthetist should fully re inflate the lung for a few minutes to improve the oxygenation of the patient

The apex of the lung is held down by a retractor and the Blalock clamp re applied to the pulmonary artery as close to the mediastinum as possible Reflux from the two branches of the pulmonary artery is prevented by the use of small bulldog arterial clips or by the use of umbilical tape or by thick silk ligatures placed round the vessels which are each encircled twice the ligatures of course not being tied but held by artery forceps The weight of

these acting through the ligatures is sufficient to stop the reflux of blood from the pulmonary end of the vessel after this has been opened The first assistant then approximates the clamp on the pulmonary artery towards the subclavian artery, which is held down by traction exerted on the two ligatures already placed around the bulldog clamp

The suture The pulmonary artery is opened by an incision made transversely or in the line of its axis, the opening should be a little larger than the open end of the systemic vessel The incision in the pulmonary artery should be well away from the Blalock clamp on its proximal side, a stay suture of 00000 special braided silk mounted on a small curved arterial needle is placed at one end of the posterior wall of the future stoma This stay suture is placed by passing the needle first from the outside of the systemic artery at the extreme edge of the posterior wall, and then over to enter the inner side of the corresponding edge of the back wall of the pulmonary artery opening, so that when tied the knot will lie outside the vessel, this suture is held and not tied A continuous suture is started and passes through the entire thickness of both vessels, it is an everting suture which brings intima to intima in contradistinction to the inverting stitch used in the surgery of intestinal anastomosis, it commences on the outside of the systemic vessel to reach the lumen of

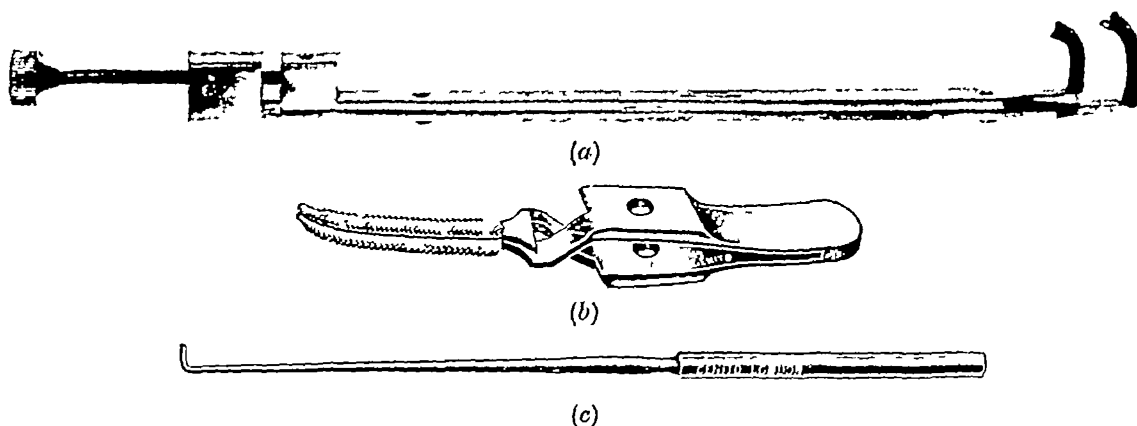


FIG 17 5

(a) Blalock clamp
(b) Arterial "bulldog" clamp
(c) Blunt hook for use in Blalock's operation (G.U Mfg Co)

that vessel and is then carried over to the inside of the pulmonary which it then re-enters from the outside so that the loop lies on the adventitia, the needle enters the inside of the systemic vessel and is made to re-enter it so that once more the loop lies on the outside the suture is then carried along the posterior wall in this manner taking as small a bite of each vessel as possible, until the whole back wall of the anastomosis has been completed No attempt is made to pull the suture taut until the line of sutures has been completed When it has been drawn up taut the first stay suture is tied and one end of it tied to the larger continuous suture. A second stay suture is passed at the other end of the back wall and this in turn is tied to the continuous suture to prevent any purse-stringing effect

The anterior wall suture is then completed with an additional stay suture applied to its centre to which the continuous suture is interrupted by an anchoring tie

Before any clamps are loosened, firm pressure is maintained on the anastomosis by a small pledglet of gauze on a forceps and this is kept up until the arterial clamps on the distal branches have been removed If at this stage the anastomosis is inspected a little oozing may be seen but need cause little alarm as it ceases usually when the Blalock clamp on the pulmonary artery has been slowly released, as the distension in the artery is sufficient to

tighten the loops of the continuous suture Occasionally an extra suture may be required to check oozing usually toward the ends of the anastomotic line but there should be no haste in using such sutures as steady pressure with a gauze mop mounted on a forceps will usually stop it When the anastomosis line looks dry the clamp on the systemic artery is released and blood at once pours from it to the pulmonary artery and sets up a characteristic thrill after further insertion if all is well the clamps are removed completely after they have been fully opened

The lung is fully re-inflated by the anaesthetist and the chest closed in layers in the usual way drainage need not be used and the intrapleural pressures are taken and if need be adjusted after the patient has been turned on to his back. (Brock advises drainage because the ninety ninth patient in his series developed a serious post-operative effusion of considerable size which remained unsuspected) In my own series the average number of aspirations required post-operatively has not exceeded one and many of the patients have not required this

Post-operative treatment If the patient has been piloted through to a successful anastomosis the condition usually improves rapidly and the chief dangers are a post-operative fall in blood pressure with the attendant risks of cerebral thrombosis in such a polycythaemic patient or of clotting in the suture line and dehydration For this reason the intravenous saline commenced before operation should be continued until the patient is taking fluids really well by mouth Anoxaemia for the first 24 hours is corrected by placing the patient in an oxygen tent penicillin is continued for at least seven days and small doses of Papaveretum or its equivalent are used. Gentle physiotherapy is employed after 24 hours and the measures employed depend largely on the clinical condition and the radiological findings as a routine a radiograph is taken the day after operation to demonstrate the condition of lung re-expansion and the amount of fluid and air present Occasionally the left lower lobe is collapsed and if this is so the child is placed on the right side with the left side uppermost and coughing encouraged in the usual way Fluid and air are aspirated if the indications are there

If progress is satisfactory which is the rule the patients are allowed out of bed on the seventh day and convalescence established

Vascular anomalies as a cause of technical difficulties Blalock has listed a formidable list of abnormal arrangements of the vessels usually employed for the anastomosis these may be in the great systemic veins or arteries or in the pulmonary arteries With good angiocardiography many of these can be diagnosed before operation One or both pulmonary arteries may be absent the whole lung circulation depending on greatly hypertrophied bronchial vessels or even from branches derived from the systemic system such as the innominate artery occasionally the pulmonary artery may be so small that only its division followed by an end to-end junction with the systemic vessel will enable an added lung flow to be established

Gross abnormalities of the vessels arising from the aorta are seen The innominate artery may be lacking and four large vessels then arise from the arch in these circumstances a carotid vessel might be selected erroneously instead of the subclavian with disastrous disturbance of the cerebral circulation On occasions the subclavian artery may arise from the aorta in the opposite thorax and pass behind the oesophagus Minor degrees of coarctation of aorta may be noted But in most patients subclavian arteries of sufficient length and calibre are available for the creation of a good anastomosis

The greatest technical difficulties encountered are (1) from the presence of troublesome oozing when the collateral vessels of the pleura overlying the pulmonary artery hamper

the dissection, (2) from shortness of the subclavian artery, if the vessel appears to be very short it should be mobilized thoroughly before a decision to divide or abandon it is made It is astonishing how an apparently unpromising vessel can in fact be used and drawn down for the provision of a satisfactory anastomosis If the subclavian artery is too short to be approximated except under high tension the anastomosis should be an end-to-end one after division of the pulmonary artery, the Blalock clamp on its proximal end being replaced by a ligature after the division

Potts' operation

Experimentally, the complete occlusion of the aorta for any length of time may cause anaemia of the spinal cord, paralysis of the legs and renal damage unless there is already an adequate collateral circulation as in patients with coarctation of the aorta. Potts (1946) has devised an ingenious clamp consisting of two flanges which when closed around the aorta pinches off an amount of aorta sufficient to allow an anastomosis to be made with the pulmonary artery and yet allows blood to flow through an aorta reduced to approximately half its normal calibre

The operation The pulmonary artery is cleared as in the Blalock operation Potts advises placing thick silk ligatures round the proximal and distal ends of the cleared vessel which is encircled twice so that it is completely, but temporarily, occluded, the descending aorta just distal to the arch is mobilized after an incision has been made through the pleura lateral to it The intercostal arteries in the mobilized section of the aorta are doubly ligated and divided and the clamp applied and slowly tightened After the adventitia over the field of compressed aorta projecting beyond the clamp has been cleared an incision of some 8 mm in length is made into it, the sutures encircling the pulmonary artery are then tied to the clamp to approximate the pulmonary artery to the aortic opening, the pulmonary artery is then opened and the anastomosis effected (see Fig 17 3)

If the opening is too large there is a danger of pulmonary oedema and of left ventricular hypertrophy developing

Brock's operation

Brock has pointed out that anastomosing a systemic to a pulmonary artery creates an arterio-venous aneurysm which in time may impose an extra burden on the heart He is in no doubt, however, that the creation of this potential danger of later heart failure is far better than leaving children to die or be incapacitated in their early life, and has performed many Taussig-Blalock operations

Many successes have now followed a direct attack upon the valvular stenosis and even by an excision operation in patients with infundibular stenosis

Valvular stenosis of the pulmonary artery In some patients with the tetralogy of Fallot the valve at the outlet of the ventricle is stenosed and Brock has dealt with this by passing a special valvulotome through the wall of the right ventricle to slit the stenosis area The chief danger of this operation is the tendency for the heart to fail before the pin-hole opening of the pulmonary outlet has been enlarged Any measure liable to diminish the cardiac output such as thoracotomy or trauma which cause a fall in peripheral pressure may lower the coronary artery flow to a fatal level This special danger indicates that the valve must be divided quickly before other attempts are made to relieve a heart that is failing during the course of the operation

In patients with pure pulmonic stenosis without the associated faults of the tetralogy the cyanosis develops rather late, as the increasing obstruction to the right side of the heart

produces a right to-left shunt through a patent foramen ovale the Blalock operation is contra indicated in these patients because in the absence of an interventricular septal defect the anastomosis of a systemic vessel to the pulmonary artery fails to relieve any of the right ventricular strain and yet imposes a further burden on the left ventricle In Brock s first 10 patients there were 5 successful results and 5 deaths but the patients were all bad risks with no possibility of doing a Blalock operation with reasonable hopes of success By October 1950 Brock and Campbell (1950) were able to present a far more encouraging picture from Guy s Hospital. These patients had been subjected to direct pulmonary valvulotomy 18 being for pulmonary stenosis and 15 with the stenosis as part of the tetralogy of Fallot there had been 10 deaths and most of these were in older patients with pure pulmonary stenosis in severe cardiac failure with right large ventricles The results in the 23 survivors have been brilliantly successful in most and good in all Since then many more patients have been operated upon by Brock with steadily improving results In their review of these patients the important point is that pulmonary regurgitation rarely takes place evidence that the principle of dividing the valves laterally (commissurotomy) has been successfully applied. The value of the operation in patients with pure pulmonary stenosis seems established and represents a brilliant achievement in cardiac surgery at the moment there is every evidence that the operation will be employed on a rising scale Already some patients who have had an artificial ductus created surgically and have begun to show signs of cardiac failure have been operated upon by the substitution of a direct valvulotomy and the closure of the subclavian pulmonary artery anastomosis At the time of writing Brock is performing many valvulotomies in the treatment of Fallot s tetralogy

The operation of pulmonary valvulotomy

The anaesthesia employed is as for other cardiac operations Attempts have been made to decrease the cardiac irregularities that develop during the procedure by employing an intravenous infusion of 0 4 per cent procaine in glucose saline solution and this is said by some to be efficient Intravenous procaine however has the disadvantage of lowering the blood pressure in some patients and as the maintenance of an adequate systemic blood pressure after the operation is essential to prevent any risk of a right-to left shunt developing if there is an atrial septal defect accompanying the pulmonic stenosis I do not use procaine except as a local injection at the site of the incision into the wall of the right ventricle The injection of procaine solution into the pericardial sac followed by a delay of some minutes is employed by some surgeons but its effect is doubtful and may have irritating effects on the visceral pericardium The incision is an anterior thoracotomy one performed through a curved infra mammary incision which is not carried too high up into the axilla The pectoral muscles and the overlying breast are dissected free from their lower thoracic attachment and held upward in a moist saline pad this dissection must be meticulous and thorough so that a clear view of the third intercostal space is obtained The pleural cavity is opened through this space almost as far back as the angle of the rib the third and fourth costal cartilages are cleared thoroughly and divided a little away from the sternum with rib spreaders in place an excellent exposure is obtained the left lung which is kept inflated by the anaesthetist throughout the operation is held posterolaterally by a light retractor Overlying fibro-fatty tissue is dissected off a wide area of the pericardium this is essential to allow a wide pericardial flap to be fashioned for periodic gentle traction on this flap may be required in the operation when it may be desired to bring the heart well over to the left for brief periods

The pericardium is opened widely just in front of the phrenic nerve A large flap is created hinged medially after horizontal incisions have been made above and below this flap can then be held by an assistant drawing on a series of linen threads on silk stay sutures so placed that effective traction upwards and to the left can be made on them when the operator wishes to bring the heart to the left, but heavy or prolonged traction must be avoided sedulously as it interferes severely with cardiac action If the pulse alters or tachycardia develops the traction is released at once and constant attention is paid to this point by Brock A small incision is made into the right ventricle, a little below the site of the infundibulum of the pulmonary artery The incision stops just short of the endo-

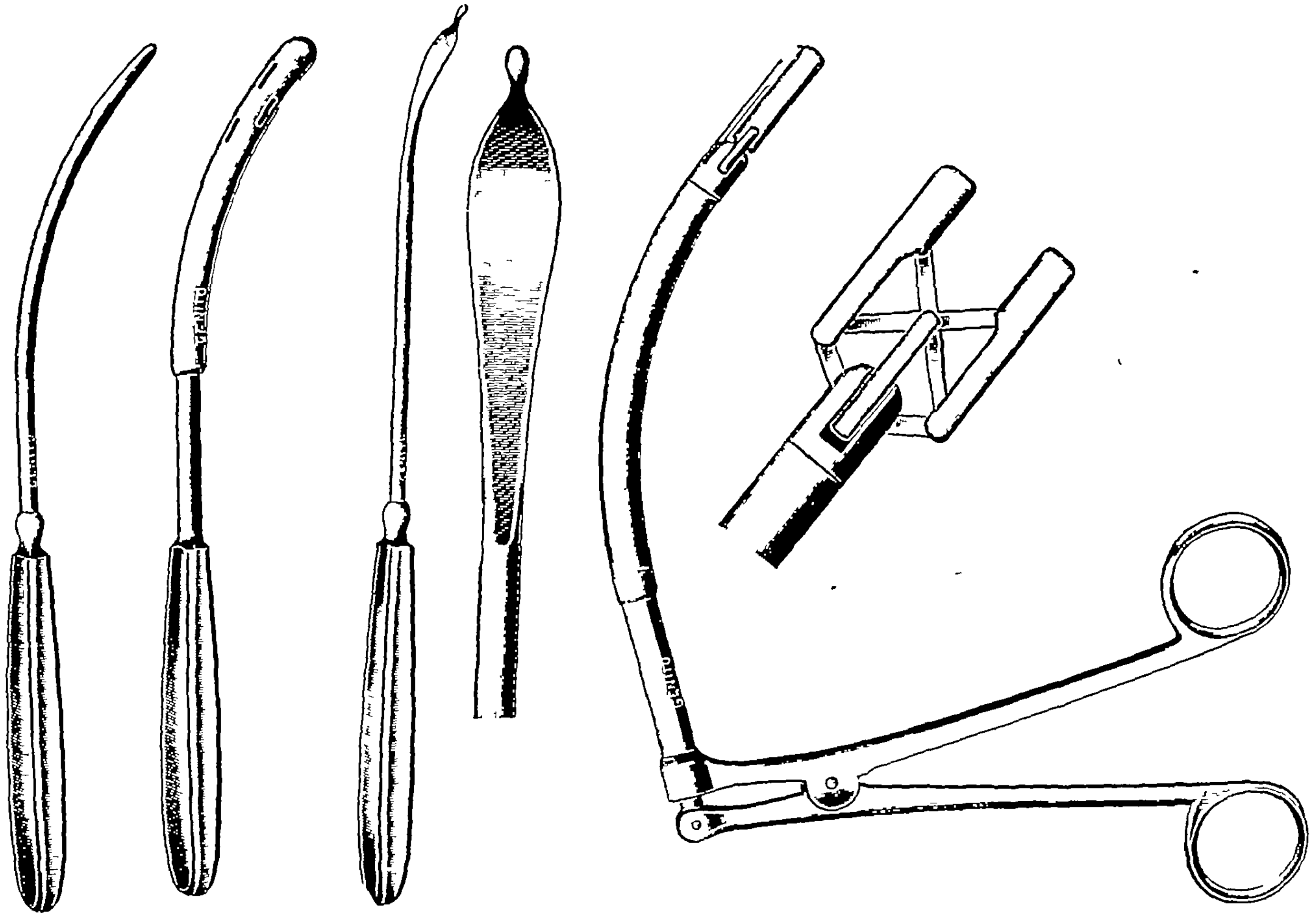


FIG 17 6—Brock's valvulotomy instruments

Reading from left to right the sound, the dilating sound, the valvulotomy knife, and the spreading dilating instrument (G U Mfg Co)

cardium, the first entry into the chamber of the ventricle being made by the special curved probe, this probe is passed up into the area of the valvular obstruction and is guided on through it to make the first real passage When the probe is withdrawn, finger pressure is applied to stop bleeding, the special valvulotome is then passed into the valve which is divided at once With suitable pauses, the valvulotomy tears are enlarged by the passage of graduated bougies (Fig 17 6), the final splitting being achieved by the dilator

Brock is insistent on the need to produce lateral cuts in the valve so that competent flaps will be left which prevent any pulmonary regurgitation The incision is closed by silk sutures passed beneath the tip of the index finger which occludes the hole in the ventricle In a straightforward case bleeding is minimal, pressure should be maintained

on the cardiotomy opening for several minutes before any attempt is made to pass the sutures by this means alone the bleeding often ceases spontaneously and the stitches can be placed at leisure

The wound is closed with or without water-sealed drainage

Infundibular stenosis In patients with the tetralogy this is commoner than valvular stenosis and Brock has resected hypertrophied muscle bands in the wall of the infundibulum by his punch This operation when successful not only increases the blood flow to the lung but diminishes the amount of impure blood passing through the intraventricular septal defect to the overriding aorta the second cause of cyanosis in patients with the tetralogy

Infundibular stenosis is not only the result of a stenotic condition but depends on the actual contraction of muscle masses in the walls of the infundibulum it is probable that

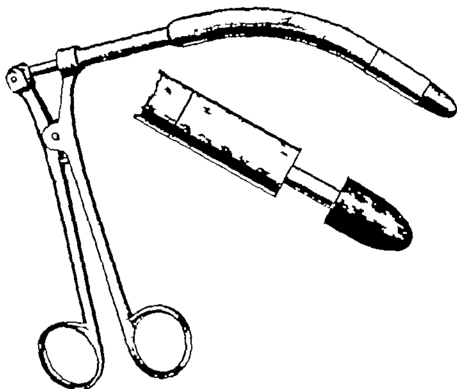


Fig 1 7 —Brock s punch for resection of the Infundibulum (O U Mfg. Co)

active contraction of these by suddenly diminishing the blood flow through the pulmonary artery and possibly by increasing the right-to left flow of blood through the septal defect because of the rise in pressure in the right ventricle is responsible for the sudden increase in cyanosis and anoxaemia which may produce the attacks of unconsciousness observed in some of these patients Direct excision of part of the wall of the infundibulum avoids the risks of an artificial patent ductus arteriosus which later may produce ill effects on the left and right ventricle and creates a better flow of blood to the lungs and relieves the pressure in the right side of the heart so that the cardiac shunt (right to left) may be decreased

The projections of cardiac muscle masses into the chamber of the infundibulum may be high or low the commonest being the high one In an important group there is a stenosis low down through the narrow ostium from which blood flows into a dilated chamber and this can be visualized radiologically because of the left sided projection from the heart

wall that is seen just below the pulmonary artery · the chamber can be seen filled with the contrast medium in angiocardiographic studies

The actual resections are done by means of a special punch passed through an incision in the right ventricle below the stricture , in one patient Brock dilated the stricture digitally with a good result The operation is undoubtedly a formidable one and has not gained the acceptance accorded to pulmonary valvulotomy With technical advances in this operation it will probably be used on an increasing scale in the treatment of Fallot's tetralogy

Transposition of the great vessels

In this serious malformation the aorta arises from the right ventricle, the pulmonary artery from the left, the pulmonary and systemic veins emptying normally into the left and right auricles respectively. Life is possible because the complete separation of the greater and lesser circulations is overcome to some effect by the existence of an interventricular septal defect Blalock's (1948) operation aims at increasing this mixture by creating an opening between the two auricles , the left-sided wall of the right auricle has a septum common to it and the right pulmonary veins so that after temporary occlusion of the *pulmonary artery and of the right pulmonary veins an opening can be made into this wall* so that the systemic venous and pulmonary venous blood can mix The logical conclusion, if the patient is fit to stand the extra intervention, is the creation of an artificial ductus Further work is proceeding on this subject in Blalock's clinic

In addition to the formidable anatomical defects there is a severe degree of pulmonary hypertension and the coronary artery blood supply is a precarious one as it receives only venous blood from the aorta which is arising from the right ventricle. Perhaps the best results would follow a surgical transposition of the systemic and pulmonary veins but such procedures are formidable and would involve many suture lines Such operations performed on the cadaver of adults have taken over two hours

Blalock and Hanlon (1950) pointed out that no obstruction exists in either circulation and that the object of surgical treatment is to let blood pass from one circuit to the other The anterior wall of the right superior pulmonary vein is covered by the right atrium and after a temporary clamp has been placed on the pulmonary artery the right superior pulmonary vein is isolated and temporarily occluded on its pulmonary side A special clamp is then placed on the right auricle in the region where the superior pulmonary vein enters it An incision is made into the superior pulmonary vein and carried on to the auricular wall and an opening created into the vein as it passes behind the atrium An atrial septal defect is produced and the operation completed by anastomosing the proximal end of a subclavian artery to the distal end of a pulmonary artery

The whole subject of complete transposition of the great vessels has recently been discussed by Astley and Parsons (1952) and possible future surgical developments suggested

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DISEASES OF THE OESOPHAGUS

INTRODUCTION

Many long standing barriers to successful oesophageal surgery have been removed the oesophagus can be exposed by a free transpleural thoracotomy or thoraco laparotomy approach in its entire length without difficulty Occasionally malignant disease of the lower pharynx and upper part of the oesophagus requires a cervico thoracic approach The menace of pyogenic mediastinitis has been lessened by the precise techniques in such matters as suture of the oesophagus by the use of adequate and effective chemotherapy and the correct management of the pulmonary and pleural complications that used to lead to the death of patients in the early days of oesophageal surgery

For many years the oesophagus was held to be not amenable to direct incisional and excisional surgery because of its lack of a serous coat and because it was wrongly assumed to have a poor blood supply

Blood supply of the oesophagus

The mucous and submucous layers have a rich freely anastomosing blood supply which endows them with the characteristic powers of rapid healing noted also in the mouth pharynx and upper respiratory passages Considerable branches of the inferior thyroid artery supply the cervical and upper thoracic portion to the mid thoracic oesophagus flows blood from the bronchial and intercostal arteries and from vessels arising directly from the aorta The lower third of the oesophagus receives large vessels arising from the left gastric and musculo phrenic arteries

During the mobilization of the oesophagus from its mediastinal bed the vessels of aortic origin must be secured carefully as troublesome bleeding will follow if they are torn close to their origins

The blood supply of the oesophagus is so good that it may be freely stripped and mobilized without fear of its wall necrosing

The anatomical importance of the junction of the portal and systemic venous systems at the lower end of the oesophagus is reflected in the development of oesophageal varices in patients with portal hypertension

Fascia of the oesophagus

A muscular tube that constantly contracts with shortening and elongation must be surrounded by a sheath in which movement is easy For this reason in the absence of pathological fixity the result of inflammation or cancerous invasion the oesophagus in its cervical and thoracic portions can be mobilized readily and freed from its surroundings at its lower end the fascia becomes condensed on each side to meet the fascia on the under side of the diaphragm forming the phreno-oesophageal ligaments which are covered in their inferior surface by peritoneum The importance of these ligaments in hiatal hernia is considered on page 501

The difficulties of end to-end anastomosis of the divided oesophagus after excision depend entirely on the degree of tension existing under such circumstances apart from

the reconstructive operation required for the correction of congenital oesophageal atresia, the indications for end-to-end repair rarely arise An adequate resection of oesophagus invaded by squamous-celled carcinoma leaves an insufficient length available for safe restoration of the tube and the act of swallowing is restored by suturing the upper segment of the oesophagus to the stomach or the jejunum.

Although without a serous outer lining, the oesophagus has a reasonably thick, vascular mucous membrane which accepts sutures well if there is no tension present The safety of oesophageal anastomosis with the stomach or jejunum depends on this layer which can be reinforced by further stitches in the stout oesophageal muscle (abundantly supplied by blood vessels) and in the outermost layer of the oesophageal fascia propria Oesophagostomy, employed occasionally for the removal of an impacted foreign body, not recoverable by oesophagoscopy, or for the excision of innocent tumours such as leiomyoma, or in the one-stage excision of diverticula, is a safe procedure if followed by accurate suture and assisted by chemotherapy The oesophagus heals well after early suture of accidental tears that may follow oesophagoscopy and gastroscopy, it is not any intrinsic defect of the oesophagus, such as lack of a peritoneal coat or an alleged poverty of blood supply, but a persistent leakage of oesophageal contents that leads to mediastinitis Post-mortem examination after such a catastrophe following oesophago-gastrostomy or oesophago-jejunostomy invariably discloses a healthy viable end of the proximal oesophageal segment and a necrosis of the gastric or jejunal side of the anastomosis, the consequence of deficient blood supply or of too much tension Such a leakage is seen most commonly in elderly arterio-sclerotic patients where stomachs have been freely mobilized by division of main vessels to enable a mediastinal oesophago-gastrostomy to be performed the blood supply from a coeliac axis greatly narrowed by pre-existent atheroma may be inadequate after such ligations (Allison, 1949) The accident is less likely if the jejunum is employed instead of the stomach

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CHAPTER 18

CONGENITAL ABNORMALITIES OF THE OESOPHAGUS

Atresia

About 4 babies in 10,000 delivered (Franklin, 1947) show congenital atresia, a far higher incidence than is generally thought. Since the trachea and the oesophagus both develop from the primitive foregut a double abnormality is possible and in practice this is seen. In 80 per cent of these abnormalities there is a blind upper oesophageal segment with a gap between it and the lower segment which is in fistulous communication with the back of the lowest portion of the trachea (Fig. 18.1). In the next commonest type both upper and lower ends of the oesophagus are blind without any tracheal communication. Very rarely the oesophagus is in open continuity but with a fistulous track into the trachea; even more unusual is the communication of both oesophageal segments with the trachea. If a gastrostomy is done in the first and commonest type, the feeds often pass up from the

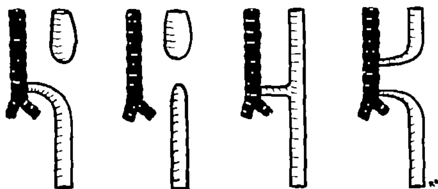


Fig. 18.1.—Oesophageal atresia.

The drawing on the left represents the commonest abnormality present, namely the blind upper pouch and the fistulous communication between the trachea and the lower segment.

stomach into the oesophagus and flow through the fistula into the bronchial tree causing a fatal asphyxia and pneumonia with widespread lung atelectasis. Moreover such an operation leaves the blind pouch incapable of emptying its contained saliva, which flows back into the pharynx and is easily aspirated into the larynx, causing the classical symptoms of choking that follow attempts at swallowing.

Clinical features and diagnosis. There may be no other abnormalities present and the birth weight is usually within normal limits. The diagnosis will be made if the association of excessive frothy oral mucus with attacks of cyanosis and choking when feeding is attempted is regarded with deep suspicion; the great excess of oral and pharyngeal mucus is a further factor causing dyspnoea. These excessive secretions are inhaled by the choking infant and respiratory complications due to infection in collapsed portions of the lung are the cause of death in most infants. The abdomen is often distended. The diagnosis is confirmed readily by radiology, lipiodol (1–2 c.c.) being instilled after the passage of a soft rubber catheter; care should be taken not to allow the spill-over of the opaque oil into the trachea (Fig. 18.3); after films have been taken the lipiodol is aspirated. All these measures should be carried out in the X-ray room.

On the straight film the stomach is seen to be distended with air and the tracheo-oesophageal communication is often clearly made out During the screening and on the study of the radiographs taken the stomach will be full of air, evidence of the presence of a fistula between the trachea and the distal segment of the oesophagus At the end of the radiological survey the oil is aspirated through the catheter A supply of oxygen must be available in the X-ray room during the procedure as severe cyanosis may develop, requiring aspiration of mucus and oxygen administration

Pre-operative treatment. Obviously oral feeding must be stopped the moment the diagnosis has been suspected Early operation is essential to prevent or lessen the risk of pulmonary complications from aspiration of pharyngeal secretions or the regurgitation



Fig 18 2



Fig 18 3

Fig 18 2 —Radiograph of oesophageal atresia

Correct method sufficient lipiodol has been instilled to outline the upper blind pouch the catheter is in position to aspirate the oil as soon as the photograph has been taken

Fig 18 3

Too much lipiodol has been placed in the dilated upper segment of the oesophagus with the consequence that some oil has spilt over into the lungs Type I of oesophago-tracheal fistula with atresia.

of stomach contents up the lower segment into the trachea But a short time spent on essential pre-operative care is required , pharyngeal secretions are aspirated, cyanosis is corrected by the oxygen tent and frequent changes of position including postural drainage will help to keep the lungs well aerated and free from secretions Penicillin is given systemically and an intravenous drip of saline and glucose is set up, great care being taken to avoid over-hydration with its attendant risk of pulmonary oedema The healthy infant takes scarcely any fluids in the first 24 hours and then 4–6 oz (120–180 c c) are swallowed in the next few days if intravenous saline is given not more than 3–4 oz (90–120 c c) should be given daily—it should be of the strength of 5 per cent dextrose and one fifth normal saline Haight favours the use of ascorbic acid and vitamin K

Operative measures Gastrostomy without surgical closure of the tracheo oesophageal fistula favours regurgitation of feeds upwards into the lungs through the tracheal fistula

The defects should be corrected at one operation the first essential being the closure of the tracheo-oesophageal fistula and this is followed by end to-end anastomosis of the oesophageal segments Quite exceptionally the lower end of the gullet may be atretic the only chance of success then lies in mobilizing the stomach as in the operation of oesophago-gastrostomy for oesophageal cancer and uniting the blind upper pouch to the thoracically placed stomach

The operative access Two approaches are possible

I Transpleural. II Extrapleural

A formal thoracotomy through the bed of the resected fifth right rib gives rapid clear and easy access to the structures requiring dissection and suture With good anaesthesia which leaves the lung fully expanded at the end of the operation (see Fig 18 4) and anti

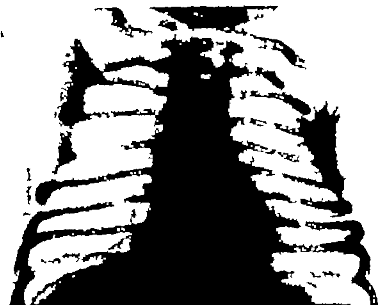


Fig 18 4 —A portable X ray photograph of the chest a day after transpleural repair of tracheo-oesophageal fistula.
The right lung is well expanded.

biotic therapy the theoretical objections to a transpleural operation are not valid if leakage occurs the dangers from an infected extrapleural space are not greatly less than those of intrapleural contamination and whichever space is involved in such a leak closed drainage will be required The extrapleural approach requires the division of several rib back ends and the pleura may be torn accidentally sometimes at the end of a time-consuming dissection Belsey (1950) who has the largest number of successful operations in the United Kingdom and Sweet (1950) of Boston prefer the transpleural approach whereas Haight (1944) and Franklin (1947) favour the extrapleural operation

The approach may be right or left sided on the right side the superior vena cava overlaps the oesophagus but after division and ligation of the azygos vein the exposure of the oesophagus is excellent In the left-sided approach if the subclavian artery is retracted towards the mid line and the aortic arch lightly depressed downwards a reasonable exposure is obtained From the level of the first thoracic vertebra to the arch of the aorta the oesophagus is to the left of the mid line But this latter slight advantage does not I

believe, justify the use of the more difficult left approach. I have used both routes extra- and intrapleurally; the right-sided one across the pleura is, in my opinion, the best.

Anaesthesia and position. Whether the approach be intrapleural or extrapleural the anaesthetist must be able to control the degree of inflation of the lungs required and control the movements of the mediastinum. Local anaesthesia alone is not satisfactory but is best combined with general anaesthesia which can be quite light. This may be given through an intratracheal tube or by a well-fitting face mask. Before the operation is started the pharynx and air passages are sucked as dry as possible.

The infant is placed in the classical thoracotomy position with a small rolled pad under the chest well up in the axilla. The security of the position is obtained by fixing the infant with narrow strapping; two pieces are required, one affixed to the skin over the uppermost anterior superior iliac spine and to the table prevents the patient from falling too much into the prone position, the second applied to the skin over the acromion process will correct any tendency to incline back too much.

The operation. (*a*) *Intrapleural operations.* Local anaesthetic solution (0.5 per cent procaine) is injected along the line of the skin incision and into the underlying muscles. The fourth or fifth rib is resected sub-periosteally and the pleural cavity opened widely, the surfaces being held apart by a small Tuffier type of single rib spreader. The anaesthetist should maintain adequate ventilation of the lung at all stages of the operation. It is held aside by small malleable copper spatulae over a moist saline mop.

(*b*) *The extrapleural approach.* Local anaesthesia (0.5 per cent novocaine) is injected along the line of the incision starting opposite the first dorsal vertebra 2 cm. away from the mid-line and curving round the tip of the scapula. The skin and muscles are divided as in a thoracoplasty incision and small sections of the second, third and fourth ribs are resected sub-periosteally back to the transverse processes. Light general anaesthesia will prevent undue lung movement while the pleura is stripped widely in the extrapleural plane; the pleura strips easily with the help of blunt pledglet dissection and the extrapleural space is rapidly developed, the pleural membrane and its contained lung being retracted lightly under a moist saline pack.

Surgical correction of the deformity. In right-sided operations, whichever approach has been used, the azygos vein is isolated, doubly ligated and divided. In the common type of deformity the upper segment is readily seen at once. The mediastinal pleura over it is incised and the opening so made is continued well down to expose the lower segment which is always far smaller than the upper blind segment in calibre. The lower segment communication with the trachea may be quite small; great care is necessary when clearing the lower segment so that no unnecessary harm is done to its blood supply. The fistula is divided as close to the trachea as possible; it is closed with interrupted fine silk sutures (00000); the lower end of the oesophagus is mobilized sufficiently to allow approximation to the upper end. Because the upper edge of the lower segment derives its blood supply from the tracheal attachment, an avascular area may be present and Belsey recommends excision of the free detached edge until the cut oesophageal wall bleeds freely. No clamps are used at any stage because of their traumatic effect on the blood vessels. The blind upper end is opened. The muscular layer of the lower segment is usually sufficiently developed to allow two layers of suture to be made, but reliance is placed chiefly on interrupted silk or fine thread sutures passed through the posterior walls of each side, each stitch taking a firm bite of the mucous membranes. The sutures are all passed before any are tied. When the back walls have been satisfactorily apposed the anterior wall of anastomosis is completed, all sutures again being passed before any are tied. It is essential

to use really fine suture material and the suture on an eyeless needle used in the Blalock subclavian pulmonary anastomosis is excellent Penicillin powder is applied to the area and the wound is closed in layers in the usual way The advantages and disadvantages of leaving a closed water-sealed drainage of the pleura or extrapleural space are subject to the usual differences of opinion I do not drain these patients as the presence of a tube increases the nursing difficulties in infants The lung is fully inflated and a radio logical examination is carried out two hours later if there is still a pneumothorax (which is unusual) air is taken off if the lung is unexpanded in any area the airways are cleared by suction through a fine rubber intratracheal catheter A tube should not be left passing through the anastomosis into the stomach as this excites secretion in the mouth and pharynx which may be inhaled and might produce infection of the suture line Gross (1946) does a gastrostomy at the end of the operation to allow temporary feeding

Post-operative treatment The essentials are (1) adequate oxygenation provided by an oxygen tent (2) skilled paediatric care in feeding to maintain a correct fluid balance and correct vitamin intake and (3) the prevention of sepsis in the pleural cavity the extra pleural space and the lungs Penicillin is given parenterally and by mouth and naso pharyngeal aspiration is continued carefully until the child is taking breast milk A continuous saline intravenous drip is not always necessary and anaemia is treated by blood transfusion. Small doses of chloral are employed to keep the infant quiet as excessive crying would prejudice the anastomosis line Feeding is started within 2–3 days of the operation and consists of a few drops of 5 per cent glucose

If a drainage tube has been used this is not removed until there is no fear of leakage and usually this is best determined about the eighth day by radiology after a few c c of lipiodol have been swallowed

The major complications are atelectasis and leakage from the suture line the first which can only be detected by the study of frequent X ray films requires suction and frequent change of position the infective aspect being controlled by antibiotics

Probably the first evidence of a leakage at the anastomosis site is the development of a pneumothorax which soon becomes complicated by pleural fluid. Such a complication requires immediate intercostal underwater drainage it is by no means a certain cause of a fatality if the lung can be kept freely expanded the leak may close even if complicated by an empyema As soon as a leakage has been detected and the pleura drained a temporary gastrostomy should be done and maintained until oesophagograms made after lipiodol has been swallowed indicate the restoration of continuity without leakage

Operative treatment of oesophageal atresia when the lower segment cannot be united to the upper one Sweet (1950) and others have provided relief for a few patients in whom an anastomosis was quite impossible at the first operation the principles are as follows The tracheal fistula is closed the upper blind pouch brought out into the neck to allow oro pharyngeal secretions to drain away so that aspiration pneumonia is prevented and a gastrostomy is performed.

At the age of two or older the left chest is opened as for excision of the lower end of the oesophagus or for carcinoma of the stomach The stomach is mobilized and brought up through the left chest into the neck where it is anastomosed with the upper pouch which has been serving as a cervical oesophagostomy

Other congenital abnormalities

True atresia partial or complete may be seen without an oesophago-tracheal fistula but is rare even more rarely there may be a fistula between the oesophagus and trachea

without atresia, I have operated on one of these, closing the fistula, but the child died on the tenth day with an empyema. Tracheo-oesophageal fistula in the adult may have a congenital basis but is probably acquired in most instances.

The faulty embryology of this area may explain the formation of mediastinal cysts containing gastric or bronchial elements. These mediastinal cysts may be blind without any tracheal or oesophageal opening, but a pedicle to the region involved in congenital tracheo-oesophageal fistula may be found (see p. 489).

An undoubted example of a double oesophagus has been recorded by Johnstone (1949). The opening of the "second" oesophagus was from the upper end of the main tube but there was no point of exit as the second one ended blindly.

Congenital stricture

It is difficult to prove the congenital nature of oesophageal stricture apart from the group just discussed; many alleged congenital strictures follow a pre-existent deficiency of the oesophageal hiatal mechanism (short oesophagus, oesophagitis, hiatal hernia).

Dysphagia of this type usually develops later in life; there is increasing difficulty in swallowing, first for solids and then for fluids, and food regurgitation accompanied by much

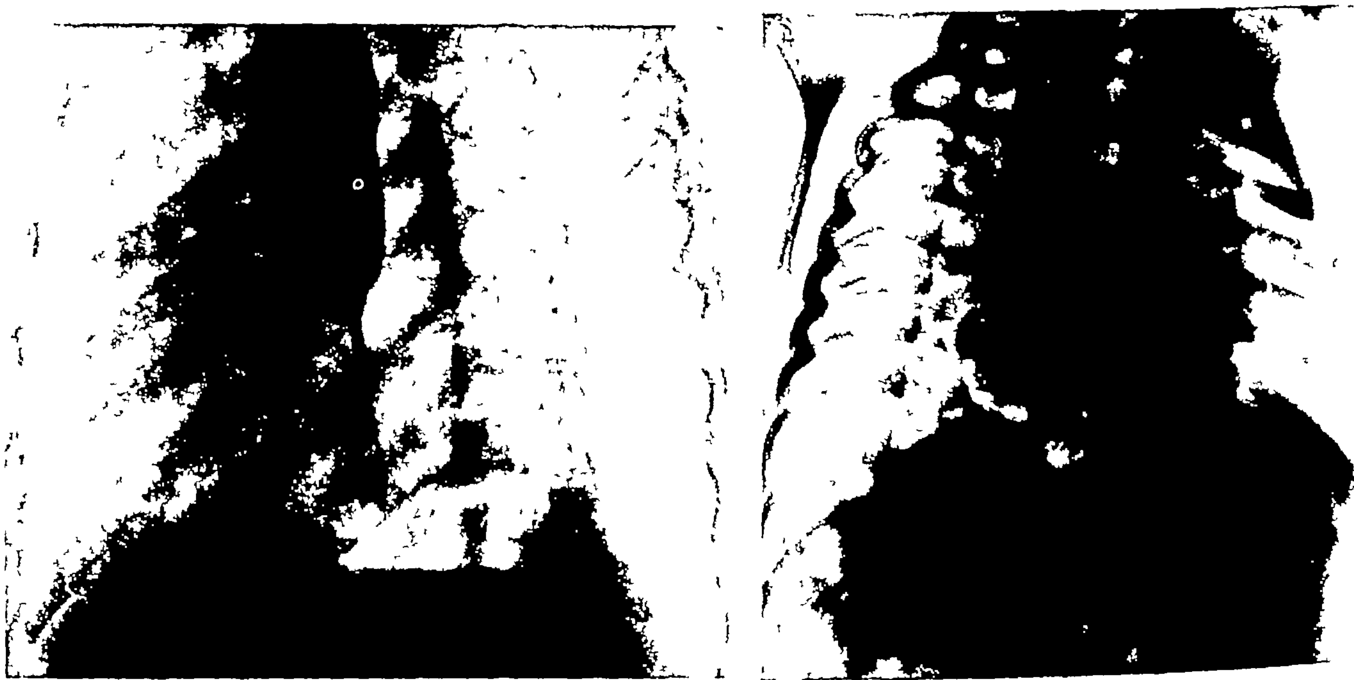


Fig. 18.5 Fig. 18.6

Fig. 18.5.—Oesophagram in a boy of 5 years.

He vomited a great deal in the first few weeks of life and had haematemesis; after a difficult early life he developed severe dysphagia and could only take fluids. The oesophagus is dilated above an area of stricture and spasm; there is a typical peptic ulcer crater in the posterior wall of the gullet and a small loculus of stomach is seen above the left leaf of the diaphragm. He was treated by oesophagoscopic dilatation and two years later he swallows most foods but has occasional severe bouts of dysphagia and vomiting.

Fig. 18.6.—A stricture of the oesophagus in a child of 6 weeks.

The stricture is secondary to a hiatal deficiency; a small portion of stomach is visible above the left leaf of the diaphragm and there is a peptic ulcer just below the area of oesophagus above the stenosed area.

frothy mucus is common. A radiograph after a barium meal shows a characteristic appearance (Fig. 18.5). The pathology and treatment of this condition is discussed fully in the section under "Oesophagitis" (page 419), but it is not inappropriate to mention here the condition of a short oesophagus, with a stricture and herniation of a portion of the stomach into the posterior mediastinum through the oesophageal hiatus of the diaphragm. Fig. 18.6

is a radiograph of a child aged six weeks with the state already obvious at this early age This condition has been well reviewed by Wylie and Field (1946)

Of six cases of intermittent haemetemesis in infants one had a congenital short oesophagus and one had a stricture In the other four cases it was believed that gastric regurgitation through a lax cardia produced haemorrhagic oesophagitis Kelly (Findlay and Kelly 1931) described nine cases of congenitally short oesophagus with partial thoracic stomach in children with ages from four weeks to nine years and ten months In eight of these oesophagoscopy and biopsy proved that there was gastric mucosa in the thorax just below the site of the stricture formation There are other cases in the literature (Haroen and Gerlings 1934 Dunhill, 1935) Astley studied 21 of these radiologically at the Children's Hospital Birmingham in 1949 and 1950 Six were diagnosed within 4–18 days after birth and fifteen between the ages of 1 to 18 months Of the 21 six already had definite strictures while five had shortening of the oesophagus The predominant symptoms were vomiting haemetemesis and melaena

In these patients the radiological stricture may often have a spasmodic element as at endoscopy the oesophagoscope can usually be passed through the stricture area Although most of the oesophageal strictures appear to be secondary to a herniation of the stomach into the thorax a truly congenital shortening of the oesophagus probably does exist (Barrett 1950)

Congenital partial atresia of the oesophagus

Rarely a partial smooth stenosis in the region of the sixth and seventh thoracic vertebrae just below the tracheal bifurcation may be present since birth these infants have usually had difficulty in swallowing which becomes aggravated when solids are introduced into the diet *Dilatation* will usually produce relief and sometimes with care these children grow up with only slight dysphagia

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CHAPTER 19

OESOPHAGEAL OBSTRUCTIONS

These may be classified as follows

I *Those due to foreign bodies*

II. *Those due to stricture*
- (a) Corrosive strictures
- (b) The result of oesophagitis
- (c) Gummatous strictures

III *Physiological derangements*
- (a) Crico-pharyngeus spasm
- (b) Pharyngo-oesophageal diverticula
- (c) Diverticula of middle and lower oesophagus
- (d) Cardiospasm

IV *Tumours of the oesophagus*
- (a) Innocent
- (b) Malignant

V *Acquired tracheo-oesophageal fistulae*

VI *Extra-oesophageal causes*

which are legion and include organic and functional central nervous system conditions, and extrinsic causes from compressing or infiltrating lesions such carcinoma of the bronchus or aneurysms

FOREIGN BODIES IN THE OESOPHAGUS

All impacted foreign bodies in the oesophagus are not radio-opaque In practice many patients are convinced that something has " stuck in the throat " , since in most instances this is not so, there is a danger that genuine impaction may be overlooked If suspicion exists and a radiograph is negative a barium swallow is of great value if the material impacted is not radio-opaque, for the oesophagus in the area of the arrested foreign body will normally show a segment of hesitant, spastic oesophagus If such is detected, oesophagoscopy should be done without delay as the dangers of perforation with subsequent mediastinitis are severe Metallic foreign bodies detected in the oesophagus should be removed at once and it is foolish to wait in the hope that they will pass on into the stomach , many would do so undoubtedly, but the hazards attending those that do not should not be accepted Occasional indications for a direct transpleural exposure of the oesophagus exist , if the foreign body has been impacted for a long period oesophagoscopic removal may be dangerous and if difficulty is experienced at the endoscopic examination the foreign body, which may be a razor-blade (Sellors, 1947), should be removed through a deliberate oesophagostomy, the opening being closed in two or three layers.

STRICTURE OF THE OESOPHAGUS

Acquired strictures are due to the sequels of oesophagitis, to trauma the swallowing of corrosive fluids and very rarely to gummatous infiltration, in Britain the commonest cause is stricture formation due to reflux oesophagitis

Corrosive strictures

Accidental or deliberate swallowing of strong acids or alkalis may result in immediate death but in the survivors stricture is common As the crico pharyngeus opens widely with the act of swallowing the worst areas of strictures are usually below this level and affect the true oesophagus usually below the aortic arch There is often a time interval of weeks before symptoms of stricture develop In the treatment of these obstructions gentle dilatation at first under direct oesophagoscopic vision is pre-eminently the method of choice and it is unusual not to obtain good results Exceptionally the treatment has to proceed along the lines of retrograde dilatation a gastrostomy is done to relieve the effects of starvation later the patient is encouraged to swallow a strong thread which usually protrudes through the gastrostomy This is attached to a first size of dilating bougie which may have to be a ureteric catheter at first and gentle traction on the thread through the mouth is executed by the patient himself gradually larger and larger bougies will pass and the patient then performs the dilatations himself by passing them through the mouth Grey Turner (1946) has constantly drawn attention to the value of this treatment



Fig 10·1 —Corrosive stricture of oesophagus.

This responded completely to gradual dilatation and the patient three years later can swallow any type of food.

Only after failure has attended the most persistent attempts at dilatations should operations such as oesophago-gastrostomy be considered

Stricture, the result of reflux oesophagitis due to oesophageal hiatus deficiency

Allison (1948) has largely clarified these hitherto ill assorted and puzzling strictures Apart from the intact mucous membrane of the stomach and first part of the duodenum the human tissues are readily inflamed by gastric secretion gastro jejunostomy performed in the presence of high gastric acidity often produces jejunitis or jejunal ulcer gastric tissue in a Meckel's diverticulum often produces ulceration bleeding and perforation If the sphincteric mechanism at the lower end of the oesophagus is deficient acid pepsin may flow back readily into the oesophagus especially during sleep when the recumbent position is associated with muscular relaxation the pool of gastric juice in the oesophagus may then cause oesophagitis which is followed by ulceration (Such a lesion is described by Barrett (1950) as reflux oesophagitis) The ulcerative process here as elsewhere is accom

panied by fibrosis which in a hollow muscular organ such as the oesophagus progressively diminishes its lumen and eventually may cause extreme fibrous constriction (Figs 19 2, 19 3)

Anatomy of hiatal deficiency. The reflux of gastric contents is normally prevented by the oblique entrance of the oesophagus into the stomach, the sphincteric action of the crural fibres of the diaphragm (especially those of the right crus) and during inspiration, by the diaphragm shortening so that the looping fibres of the constricting right crus pull the oesophagus down into the abdomen, so increasing the obliquity of its angle with the stomach This mechanism is perfectly described by Allison (1951) At the same time the



FIG 19 2



FIG 19 3

FIG 19 2—Stricture of oesophagus with a small gastric herniation in a man of 74 years

At the age of 30 years, severe "dyspeptic symptoms" associated with a proved duodenal ulcer At the age of 70 years severe dysphagia developed after complete cessation of all indigestion Oesophagoscopy revealed all the features of oesophagitis dilated can swallow any food a year later The patient was referred to the clinic with a diagnosis of carcinoma of the oesophagus

FIG 19 3—Radiograph of a patient with advanced pulmonary tuberculosis and a positive sputum

Dysphagia was gross It is caused by oesophageal stricture and a cone of stomach containing gas can be seen in the posterior mediastinum The dysphagia had been preceded by years of dyspepsia

oesophago-diaphragmatic ligaments tauten and aid in the general effect produced by the pinch-cock action of the diaphragmatic oesophageal hiatus The circular muscle fibres at the lower end of the oesophagus appear to play no part in preventing gastric regurgitation as their free division in the operation of cardiomyotomy for the relief of cardiospasm is not followed by gastric reflux

Paralysis of the left phrenic nerve might be expected to cause hiatal insufficiency but in practice this is not so, and the development of reflux of gastric contents does not follow the operation of phrenic nerve interruption even when this is accompanied by a considerable

upward displacement of the diaphragm often accentuated in patients with pulmonary tuberculosis who are being treated by an artificial pneumo peritoneum In such patients the cardia remains in the normal site with reference to the level of vertebrae and does not lose its normal obliquity It is not altogether fanciful to suppose that the crura of the diaphragm receive a nerve supply other than from the phrenic nerve

Oesophageal hiatus deficiency is seen in infants and adults The pathological effects in both groups are the same surface ulceration of the oesophageal mucous membrane may be followed by a typical peptic ulcer and fibrosis and spasm follows here as in the pylorus when a gastric or duodenal ulcer is present (see Fig 10 2)

This condition of oesophagitis ascending fibrosis (Kelly 1939) peptic ulceration and shortening of the oesophagus all due to hiatal deficiency undoubtedly explains most instances of oesophagitis But Barrett (1950) has been careful to indicate an important but less common type of patient in this group there is a congenitally short oesophagus with a cone of stomach in the thorax examination on autopsy subjects and by oesophagoscopy in the living shows no evidence of inflammation in the oesophagus above the stomach but that ulceration of the chronic peptic type has developed in the segment of misplaced stomach itself

Clinical features of peptic ulcer of the oesophagus, oesophagitis and oesophageal stricture Since Allison drew attention to these patients they are seen in increasing numbers in thoracic clinics It is most important to recognize them and each year patients are seen who have been diagnosed as suffering from carcinoma of the oesophagus others have been referred as tuberculous or gummatous strictures (Fig 19 3) fuller investigation reveals a group of treatable patients with a good prognosis

Although hiatal deficiency is the cause of the condition all patients with gastric herniation into the posterior mediastinum do not develop oesophagitis and its sequelae just as all patients who have undergone gastro-enterostomy do not suffer from subsequent gastro jejunal ulceration But the constant reflux of gastric juice into the oesophagus in certain patients especially those with hyperchlorhydria causes oesophagitis These patients usually have a long history of upper abdominal dyspepsia often suggestive of cholecystitis or peptic ulcer which gradually gives way to a story of increasing dysphagia which is not necessarily progressive there being notable remissions The pain which has been a long standing complaint often disappears with the advent of dysphagia as happens so often in pyloric stenosis the result of a pyloric peptic ulcer of long duration But the formation of a peptic ulcer in the oesophagus causes heartburn and pain situated behind the sternum and usually in the back in the area of the eighth dorsal vertebra Vomiting the result of oesophageal regurgitation is a constant and distressing feature and weight loss may be severe Regurgitation is often induced by bending down in the act of tying shoe-laces or gardening Anaemia is sometimes severe

The radiological appearances may show a stricture only without sign of an ulcer crater and there is a gastric hernia with a typical stomach mucosal pattern evident If the ulceration has subsided to be replaced by a healing fibrosis the appearances of stricture are the predominant feature It is important to remember that part of the stricture appearance is due to spasm at oesophagoscopy in these patients after a preliminary dilatation it is exceptional not to be able to pass the instrument right through into the stomach

Oesophagoscopic appearances It is unsafe to diagnose this condition on radio logical appearances alone and the patients must be examined with the oesophagoscope this is safely and easily carried out under local anaesthesia as an out patient procedure The gullet above the affected area is dilated and contains typical frothy moist contents

The appearances of oesophagitis vary from congestion and oedema to violent crimson red colouration indicative of extreme inflammatory hyperaemia · when severe congestion is present the surface bleeds readily In some areas patches of leucoplakia vary with surface and deep ulceration The appearances mentioned are rarely evident in that part of the gullet above the level of the aortic arch If there is no stenosis the oesophagoscope can be passed on into the stomach which can be entered without any manœuvre being necessary



Fig 19 4 Fig 19 5

Fig 19 4 —Stricture of oesophagus with peptic ulceration and hiatal defect

The stomach is drawn up as a cone into the thorax above the level of the left leaf of the diaphragm In this lateral view the diaphragmatic leaf shown is that of the higher placed right side

Fig 19 5 —Oesophageal stricture in a man of 46 years Severe dysphagia of a year's duration followed a long history of dyspepsia

The appearance of a defective filling just above the stricture was due to an impacted damson stone This was removed at oesophagoscopy and the stricture dilated biopsy of tissue just beyond the limit of stricture revealed gastric mucosa, thus confirming the radiological evidence of gastric herniation with typical mucosal pattern

to negotiate the gastro-oesophageal junction which is normally placed obliquely to the left, in these patients the oesophagus enters the stomach in a direct line of continuity The area of the cardia may not be easy to define as the instrument reaches the stomach at a level higher than the normal 40–42 cm from the upper incisor teeth Gastric mucosa will be found in biopsy specimens taken at the time of the oesophagoscopy at a much higher level than in the normal subject These histological examinations performed before Allison's work was widely known were often referred to as islets of gastric, heterotopic

mucous membrane and ulceration in these alleged areas of misplaced tissue was held to be responsible for the condition

When stenosis and ulceration are present the oesophagus above the constricted area shows the appearances of chronic oesophagitis but the ulcer which usually lies just distal to the start of the stricture is not easily seen though the presence of polypoid and granulation tissue suggests one is there

The stricture responds to gentle dilatation and once this has been done fluid wells up from the stomach

Oesophago-gastrostomy as a cause of oesophagitis and its sequelae The sphincteric mechanism is destroyed when the oesophagus is resected for malignant disease and the upper end of the gullet is anastomosed to the stomach after it has been mobilized and brought up into the thorax This operation and the oesophago-gastrostomy that used



Fig 10·6 —Barium swallow in a woman after oesophago-gastrostomy following excision of the lower third of the gullet for carcinoma.

Dysphagia nine months later was due to oesophagitis and ulceration as confirmed by oesophagoscopic examination.

to be performed for the relief of cardiospasm is liable to be followed by oesophagitis and peptic ulceration This hazard can be avoided in resection of the lower end of the oesophagus for cancer by anastomosing the upper end of the gullet to a jejunal loop and not to the stomach but for high oesophageal resections the stomach can be mobilized and placed higher in the chest than can a jejunal loop and the risk of later oesophagitis must be taken There is no need however to employ the operation of oesophago-gastrostomy in any patient with cardiospasm as better results follow the cardiomyotomy operation of Heller (see

p 443), which leaves the pinch-cock mechanism of the diaphragmatic crura intact The careful follow-up of Barret and Franklin (1949) on patients who have been subjected to oesophago-gastrostomy for cardiospasm leaves no room for doubting the high incidence of serious oesophagitis that follows the procedure

Treatment of oesophagitis due to hiatal hernia. The repair of the hernia before ulceration and stricture formation has developed is the logical course Since the herniation can be diagnosed in infants and adults before the grosser pathological complications have ensued, operation should be most carefully considered, operative details are given in Chapter 26

If the stomach has ascended too far and there is considerable oesophageal fixity, the result of ulceration and fibrosis, the replacement of the stomach into the abdomen may not be possible even after thorough mobilization · if the symptoms are those of heartburn, indigestion and pain a medical regime is employed as for peptic ulcer in the stomach and duodenum In addition to alkalis and dietetic measures relief from anxiety and periods of bed rest help correction of the mechanical aspect of the problem is sought by making the patient sleep in the upright position, so that less gastric regurgitation will follow than in the lying-down state

If dysphagia results from stenosis oesophagoscopic dilatations, which may have to be repeated at intervals are used in addition to the medical measures It must always be remembered that the relief of the obstructive state may well be followed by increase in gastric regurgitation and, especially in children, severe vomiting may follow as the result of an immediate post-operative exacerbation of the oesophagitis above the site of the dilated stricture When this unhappy result follows successful dilatation it may be an indication for the operation of oesophago-jejunostomy described later this operation, however, is possible only in the older age group of children and adults because of the difficulty of obtaining a sufficiently long jejunal loop in children

Oesophago-jejunostomy for peptic ulceration of the oesophagus. If medical treatment combined with oesophagoscopic dilatation, when needed, fails to enable the patient to lead a reasonable life, the stenosed and ulcerated area may be excised and the continuity of the alimentary canal restored by anastomosing the proximal end of the oesophagus to the jejunum (Allison) This operation unfortunately may be followed by loss of weight, diarrhoea and steatorrhoea

The operation of oesophago-jejunostomy. The preliminary toilet of the oesophagus and its temporary blocking by a tampon is a most important prophylaxis against the danger of post-operative pulmonary complications, the results of the regurgitation of its infected contents into the pharynx (Allison)

With the patient in the true lateral thoracic position the chest and abdomen are opened widely through a thoraco-laparotomy incision with complete excision of the left eighth rib and its cartilage the pleural cavity is opened and the diaphragm divided down to the oesophageal hiatus as in the operation for lower oesophagectomy or total gastrectomy (see p 449)

The jejunal loop is prepared before the oesophagus is mobilized A Roux loop is employed The site of section of the jejunum is carefully made and this should be some 10 inches from the duodeno-jejunal junction To preserve a good supply to the jejunal loop the primary trunks of the jejunal vessels are isolated and divided proximal to the first arch and three of these vessels can usually be divided with safety but the vascularity of the loop must be tested before the actual division this can be assessed by digital compression of the vessel before ligation The mesentery is then incised up to the selected

point of intestinal section and the vascular arcade near to the bowel is divided. A sufficient length of jejunum is essential to avoid tension on its vessels when it is placed in the mediastinum The cut end of the loop is then closed with two layers of suture one through the mucosa and one to invert the serous coat this loop is then passed through a hole in the transverse mesocolon as near to the splenic flexure as possible and is led on through the lesser sac into the posterior mediastinum

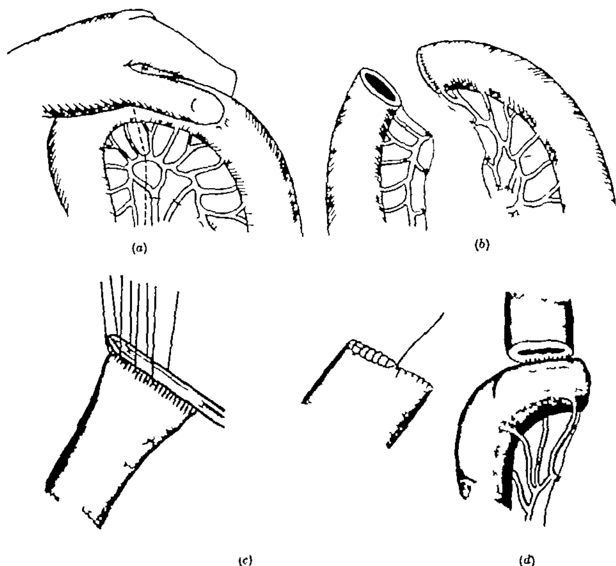


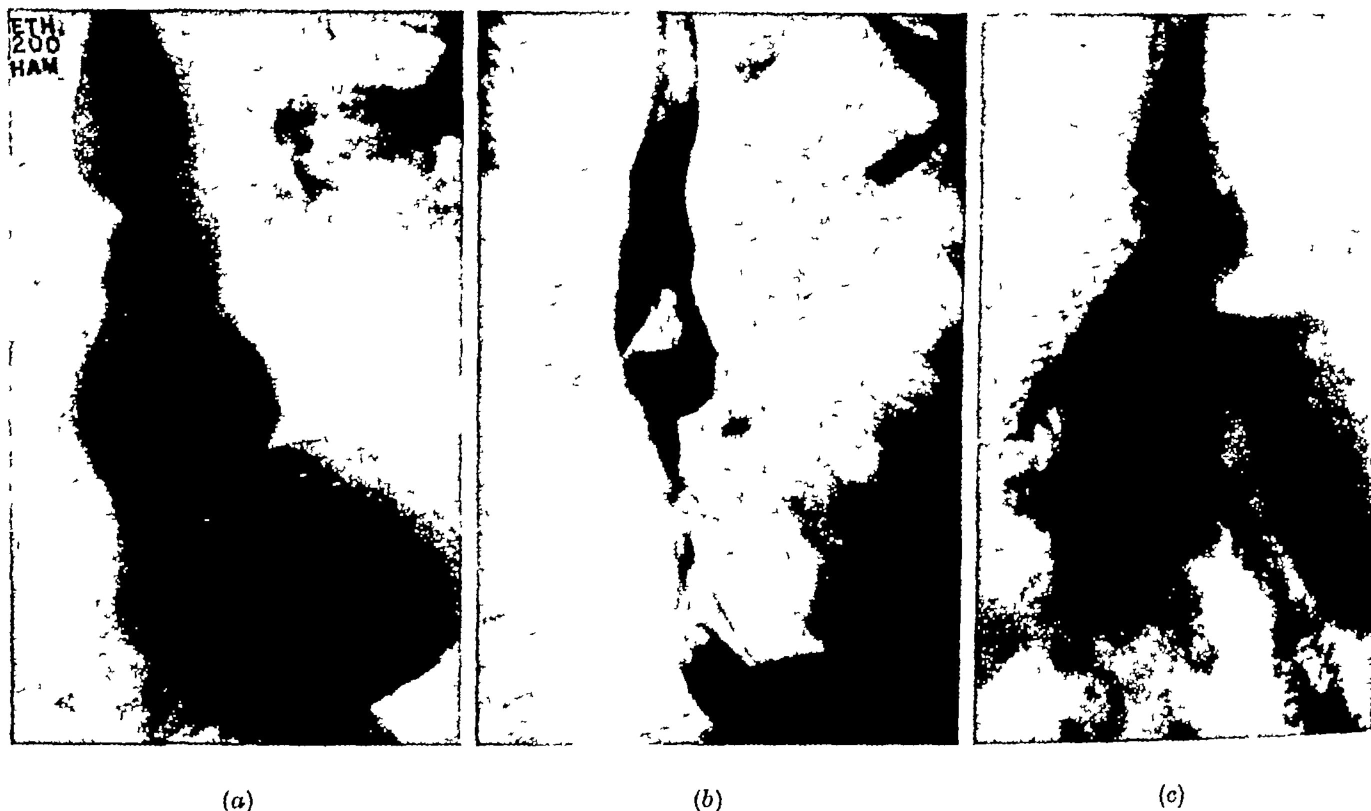
Fig 10·7

(a) and (b) Diagram illustrating steps in the preparation of a jejunal loop
(c) Closure of the open end of the jejunal loop which will be employed for oesophago jejunostomy
(d) First stage of the anastomosis of the oesophagus to the jejunum.

The oesophagus is then mobilized this may be difficult because of peri-oesophageal adhesions and there are usually many vascular matted lymphatic glands in the region of the stricture and ulcer After the oesophagus has been thoroughly freed and cleared it is divided at its junction with the stomach between a pair of Schumacher s clamps the gastric end being closed with two layers of sutures An incision is then made into the anti mesenteric border of the isolated jejunal loop without the use of clamps which may damage the impoverished blood supply the opening should correspond with the size of the oesophageal lumen above the stricture Two stay sutures are then inserted into the medial lateral edge of the oesophagus just above the point selected for the section The stenosed

area of the oesophagus is then cut away and a series of interrupted sutures applied to the fascia propria and muscle of the posterior wall of the oesophagus and passed through the sero-muscular coat of the jejunum these sutures are tied and are followed by a further series of interrupted thread or silk sutures through all coats of the posterior wall of the oesophagus and that of the jejunal stoma None of these are tied until all have been passed When this has been done there should be no suggestion of any tension

The mucous membranes of the anterior wall are then united by interrupted sutures and reinforced by a second layer through the oesophageal muscle and the jejunal mucosa The area of anastomosis is then fixed by a few interrupted sutures to the parietal pleura and a flap of pleura lifted from the chest wall may be wrapped around it The proximal



(a) (b) (c)

Fig 19 8—Radiographs of a woman of 64 years

There was a long history of dyspepsia for 10 years In January 1950 (Fig 19 8 (a)) the symptoms were those of regurgitation with pain in the upper chest and back Nine months later severe dysphagia had developed and the radiographic appearances had changed to one of stricture in addition to hiatal hernia (Fig 19 8 (b)) The stricture was dilated but caused severe post-operative pain of a burning character associated with constant regurgitation of food and gastric juice she lost weight rapidly The medical regime was abandoned and oesophago jejunostomy was done with relief of dysphagia (Fig 19 8 (c)) She has some diarrhoea a year later

end of the divided jejunum is then sutured to an opening made into the side of the jejunum below the anastomosis to complete the Roux Y

The abdomen, diaphragm and chest wall are closed in the usual way with a water-sealed drain left in the pleural cavity

The post-operative course follows the line of that after oesophagectomy for carcinoma of the oesophagus

The radiograph of the child shown in Fig 19 9 is of interest She was suffering from a typical oesophageal ulcer with a diaphragmatic hernia which was well seen subsequently at operation This child had not been able to take solids all her life dilatation was followed by a great increase in regurgitation In spite of her young age (8) she was exceptionally tall and a jejunal loop of sufficient length was obtained the actual operation planned was that of oesophago-gastrostomy but the laparotomy revealed an accommodat-

ingly long mesentery The operative result has been followed by a real capacity for food but poor gain in weight and at no time have there been any digestional disturbances

(a)

(b)



(c)

Fig 19-9

(a) Barium swallow in a child of 8 years with dysphagia all her life
(b) After oesophago jejunostomy (see text)
(c) Portion of the oesophagus after resection

Note the great thickening of the oesophageal wall and the strictured lumen the segment to the left shows portion of the thoracic stomach below the inflamed and thickened oesophagus

following the operation It is I believe quite exceptional to be able to perform oesophago jejunostomy at such a young age

Oesophago-gastrostomy in the treatment of stricture with ulceration If



(a)

Fig 19 10—Boy aged 4 years Dysphagia since birth after haematemesis and vomiting, he was nurtured entirely on fluids

The upper third of the oesophagus is dilated above the strictured area which leads to the thoracically placed portion of stomach

(a) The stricture was easily dilated but this was followed by persistent vomiting and great loss of weight A high oesophago gastrostomy was performed with the anastomosis just below the aortic arch, recovery was uneventful For the last two years there have been no symptoms and considerable weight gain

(b) Straight radiograph showing high thoracic portion of the stomach. This boy's sister, now aged 2 years, has the same condition—

(c) and has been successfully treated by the same operation





(c)

dilatation and a medical regime fails to relieve severe symptoms oesophago jejunostomy is preferable to oesophago-gastrostomy which perpetrates the condition that has caused the oesophageal ulceration In children below the age of 10–14, however it is usually impossible to fashion a jejunal loop long enough for safe anastomosis without tension to the oesophagus and Belsey has used the stomach in very young children for the anastomosis after he has excised the lesser curvature with the object of removing a large area of the acid and pepsin producing mucous membrane Wangensteen has had successful results in the treatment of peptic ulcer of the oesophagus by executing a wide sub total gastrectomy to remove the irritating effects of gastric reflux Oesophago-gastrostomy without the addition of Belsey s resection procedure has given surprisingly good results in spite of its faulty physiological bases it should however be reserved for the most severe types of obstruction which remained unrelieved or aggravated by oesophagoscopy and dilatation and where the small size of the patient renders an oesophago jejunal anastomosis impracticable because a sufficient length of jejunum cannot be fashioned. If the stomach is used the anastomosis with the oesophagus should be made just below the aortic arch so that the oblique and kinked entrance so obtained will prevent the regurgitation of gastric contents (see Fig 10 10 (c)) the oesophagus above this level appears to be resistant to the development of the changes associated with reflux oesophagitis lower down An example of this operation is shown in Fig 10 10

PHYSIOLOGICAL DERANGEMENTS OF THE OESOPHAGUS

No patient with dysphagia should be labelled as functional or spasm until full investigations have been carried out in any clinic dealing with dysphagic patients many suffer from nervous functional disorders and a few from serious organic disease of the central nervous system The true neurotic almost invariably complains that the difficulty is in the lower portion of the pharynx and rarely in the true oesophagus in addition to the difficulty in swallowing there is often a complaint of suffocation the whole story being detailed with a wealth of dramatic detail usually absent from the matter-of fact history given by the patient with organic obstruction but in spite of the lurid story a clinical examination of the thyroid gland the whole neck and an endoscopic view of the pharynx and larynx provide negative results and a barium meal swallow shows no obstruction and no deviation from the normal act of deglutition. If a full neurological examination shows no organic abnormality a diagnosis of globus hystericus can be made and the patient should be treated psychologically

Disorders in the co-ordination of the oesophageal muscles not infrequently exist and whatever their etiology they produce anatomical variations that are readily demonstrated especially by radiology The deviations include hypertrophy or dilatation of the oesophagus over large areas alternation of dilatation and contraction persistent contraction of the circular muscular fibres at the upper or lower end of the oesophagus and diverticulum formation

The act of swallowing When the bolus of food is driven forcibly by the contractions of the pharyngeal muscle into the upper end of the oesophagus a strong wave of peristalsis is initiated and passes down to the oesophago-gastric junction this is the *primary wave* of Templeton (1944) and depends for its integrity on a precise relaxation of the crico pharyngeus muscle just before the food reaches it similarly the circular muscle of the lower two inches of the oesophagus relaxes if the peristaltic wave is to force the bolus on

into the stomach If either of these "sphincters" fail to relax, well-recognized pathological conditions such as the upper dysphagia of the Patterson-Brown-Kelly or Plummer-Vinson syndrome or the lower obstruction of cardiospasm may develop As discussed later this faulty relaxation may well play a part in diverticulum formation When the lower end of the oesophagus is obstructed by growth, the peristaltic wave is often abnormal, just as it is in early examples of cardiospasm

This major, primary peristaltic wave is supplemented or replaced in certain pathological conditions by secondary and tertiary waves The secondary waves, best seen in cases of obstruction (Johnstone, 1949), start at the level of the aortic arch The tertiary



Fig 19 11 Fig 19 12

Fig 19 11 —At screening, most irregular contractions of the oesophagus were noted with an apparent area of persistent spasm in the mid-oesophagus as shown in this radiograph. Oesophagoscopy revealed a carcinoma of the stomach including the lower end of the oesophagus

Fig 19 12 —Corkscrew oesophagus in a patient with a mid-thoracic diverticulum

waves are irregular segmental contractions, noted in the lowest third of the oesophagus where unstriped muscle fibres alone exist The physiological significance of these contractions is imperfectly understood but they can be produced by abnormal stimuli such as inflation of a balloon placed in this oesophageal segment They are seen in patients without any dysphagia, especially in the elderly during routine barium meal examinations, but occasionally in patients with irregular attacks of difficulty in swallowing but in whom oesophagoscopy reveals no abnormality except perhaps enlarged mucous membrane folds Allison and Johnstone have noted them in the early stages of cardiospasm Their occurrence may be responsible for the condition known as "corkscrew oesophagus" In Fig 19 12,

in addition to the corkscrew appearance with apparent false diverticula the presence of a true diverticula of the mid thoracic oesophagus will be noted and this radiograph supports the view that pulsion diverticula are often associated with faulty muscular contractions (see pharyngo-oesophageal diverticula below)

Quite exceptionally a simple spasm of the lower third of the oesophagus is noted the condition must not be diagnosed as such on the results of a barium oesophageal picture and oesophagoscopy should be done to exclude a more serious lesion A series of barium examinations will usually show that at different times the segments affected by the spasm alter but the condition as far as I know is only seen in the lower portion of the oesophagus which has unstriped muscle in its wall This type of spasm may be present when there is a serious abdominal lesion and is seen even in very young infants

The Patterson-Brown Kelly or Plummer-Vinson syndrome

Though properly beyond the field of thoracic surgery spasm of the crico-pharyngeus muscle produces dysphagia which often results in the patient arriving at a thoracic surgical service and a brief account of the condition is indicated here It seems unfair to classify this disease as hysterical or functional for the patients who are invariably women have all the signs and symptoms of hypochromic anaemia possibly the deficient iron intake is secondary to a hysterical dysphagia but the patients when seen have organic disease affecting the mucous membrane of the lips which often show cracks at the edges of the tongue which is small smooth and red and of the pharyngeal mucosa The crico pharyngeus muscle is in tight spasm but with care an oesophagoscope under local anaesthesia can be passed The blood picture is typical with a haemoglobin count that may be below 30 there is frequently an achlorhydria and the spleen is usually palpable If unrelieved the condition may pass on into a post-cricoid carcinoma

Treatment This is essentially by a full long-continued course of iron therapy preceded by a single oesophagoscopic examination the passage of the oesophagoscope is sufficient to dilate the crico pharyngeus and then a full diet accompanied by intensive iron therapy will cure the condition Not only does the oesophagoscopy play a large part in the treatment but it enables any suspicion of the development of a post-cricoid carcinoma to be confirmed or dispelled.

Pharyngo-oesophageal diverticula

Although these diverticula arise in the neck and are truly pharyngeal diverticula they may produce dysphagia by altering the function of the upper oesophagus The *mouth* of the sac invariably lies in the weak area of the posterior wall of the pharyngo-oesophageal junction between the oblique fibres of the inferior constrictor muscle of the pharynx and the transversely placed crico pharyngeus muscle at the start of the oesophagus The wall of the diverticulum consists largely of mucous membrane but contains muscle fibres once the sac begins to bulge it tends to enlarge towards the left side of the neck possibly because there is more space between the oesophagus and the carotid artery on the left than on the right subsequent to this left-sided protrusion the diverticulum may come to lie behind the upper part of the oesophagus and descend well into the thoracic inlet

Etiology The condition is almost unknown in the young and is usually present well after middle age and more commonly in males The diverticulum is probably the result of pulsion forces and at operation the fundus of the sac is notably free from adhesion to surrounding structures so that a traction element can hardly be involved indeed the

into the stomach If either of these " sphincters " fail to relax, well-recognized pathological conditions such as the upper dysphagia of the Patterson-Brown-Kelly or Plummer-Vinson syndrome or the lower obstruction of cardiospasm may develop As discussed later this faulty relaxation may well play a part in diverticulum formation When the lower end of the oesophagus is obstructed by growth, the peristaltic wave is often abnormal, just as it is in early examples of cardiospasm

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Fig 19 12 —Corkscrew oesophagus in a patient with a mid thoracic diverticulum

waves are irregular segmental contractions, noted in the lowest third of the oesophagus where unstriped muscle fibres alone exist The physiological significance of these contractions is imperfectly understood but they can be produced by abnormal stimuli such as inflation of a balloon placed in this oesophageal segment They are seen in patients without any dysphagia especially in the elderly during routine barium meal examinations, but occasionally in patients with irregular attacks of difficulty in swallowing but in whom oesophagoscopy reveals no abnormality except perhaps enlarged mucous membrane folds Allison and Johnstone have noted them in the early stages of cardiospasm Their occurrence may be responsible for the condition known as " corkscrew oesophagus ' In Fig 19 12,

in addition to the corkscrew appearance with apparent false diverticula the presence of a true diverticula of the mid thoracic oesophagus will be noted and this radiograph supports the view that pulsion diverticula are often associated with faulty muscular contractions (see pharyngo-oesophageal diverticula below)

Quite exceptionally a simple spasm of the lower third of the oesophagus is noted the condition must not be diagnosed as such on the results of a barium oesophageal picture and oesophagoscopy should be done to exclude a more serious lesion A series of barium examinations will usually show that at different times the segments affected by the spasm alter but the condition as far as I know is only seen in the lower portion of the oesophagus which has unstriped muscle in its wall This type of spasm may be present when there is a serious abdominal lesion and is seen even in very young infants

The Patterson-Brown Kelly or Plummer-Vinson syndrome

Though properly beyond the field of thoracic surgery spasm of the crico pharyngeus muscle produces dysphagia which often results in the patient arriving at a thoracic surgical service and a brief account of the condition is indicated here It seems unfair to classify this disease as hysterical or functional for the patients who are invariably women have all the signs and symptoms of hypochromic anaemia possibly the deficient iron intake is secondary to a hysterical dysphagia but the patients when seen have organic disease affecting the mucous membrane of the lips which often show cracks at the edges of the tongue which is small smooth and red and of the pharyngeal mucosa The crico pharyngeus muscle is in tight spasm but with care an oesophagoscope under local anaesthesia can be passed The blood picture is typical with a haemoglobin count that may be below 30 there is frequently an achlorhydria and the spleen is usually palpable If unrelieved the condition may pass on into a post-cricoid carcinoma

Treatment This is essentially by a full long-continued course of iron therapy preceded by a single oesophagoscopic examination the passage of the oesophagoscope is sufficient to dilate the crico-pharyngeus and then a full diet accompanied by intensive iron therapy will cure the condition Not only does the oesophagoscopy play a large part in the treatment but it enables any suspicion of the development of a post-cricoid carcinoma to be confirmed or dispelled.

Pharyngo-oesophageal diverticula

Although these diverticula arise in the neck and are truly pharyngeal diverticula they may produce dysphagia by altering the function of the upper oesophagus The mouth of the sac invariably lies in the weak area of the posterior wall of the pharyngo-oesophageal junction between the oblique fibres of the inferior constrictor muscle of the pharynx and the transversely placed crico pharyngeus muscle at the start of the oesophagus The wall of the diverticulum consists largely of mucous membrane but contains muscle fibres once the sac begins to bulge it tends to enlarge towards the left side of the neck possibly because there is more space between the oesophagus and the carotid artery on the left than on the right subsequent to this left-sided protrusion the diverticulum may come to lie behind the upper part of the oesophagus and descend well into the thoracic inlet

Etiology The condition is almost unknown in the young and is usually present well after middle age and more commonly in males The diverticulum is probably the result of pulsion forces and at operation the fundus of the sac is notably free from adhesion to surrounding structures so that a traction element can hardly be involved Indeed the

smooth outline of the fundus is in complete contrast to the spiky apex of the rare traction diverticula seen in the thoracic oesophagus If there is a considerable and progressive area of weakness in Killian's triangle the high intrapharyngeal pressure will tend to drive the mucous membrane out beyond the wall of the pharynx If the crico-pharyngeus muscle is slow to relax the effect of this pressure will be accentuated and Johnstone has noted in the early stage of diverticula formation that there is a slight hesitation before the barium enters the oesophagus , this may well be due to slow relaxation of the crico-pharyngeus muscle, possibly the result of inco-ordination Negus (1950) has reported his conviction based on accurate observation that slight dysphagia precedes the diverticulum formation The weak area described is present in all humans, but only a few develop pouches, which





FIG 19 13 FIG 19 14

FIG 19 13—Barium swallow showing a very small diverticulum in the classical site
This patient had slight dysphagia and there was spasm of the crico-pharyngeus When the actual barium swallow was studied a marked hesitancy of relaxation of the crico pharyngeus was obvious

FIG 19 14—A well developed pharyngo-oesophageal diverticulum.
Note that the pouch has filled before any barium has passed beyond the crico pharyngeus area where the bolus was held up for a considerable time

follow faulty co-ordination of deglutition muscles in which the crico-pharyngeus is chiefly concerned This disordered mechanism may be due to chronic hypopharyngitis and fibrosis It is certain that a small diverticulum as shown in Figs 19 13, 19 14 cannot be the cause of the slight dysphagia present but is indeed the result of it If dysphagia is present with such a small diverticulum the surgical duty involves an inspection and dilatation of the crico-pharyngeus , equally important in the patient with a large diverticulum is such an examination and dilatation in addition to the excision of the sac

The weakness of the area between the inferior constrictor muscle and the oesophagus may be due to a constant attrition of this area against the cervical vertebral column, especially in patients with spinal osteo-arthritis The higher male incidence may be due to the larger

larynx and the increased friction of this area of the pharyngeal wall against the vertebral column during deglutition

Symptoms The sufferer is usually elderly and has had symptoms for two to three years often after years of minor dysphagia These symptoms may be quite bizarre though of them all progressive dysphagia is the commonest The patients locate the difficulty in swallowing just above the sternum and many describe an intermittent obstruction which can be cleared by odd contractions of the muscles of the neck associated with peculiar grimaces The sac itself may become full of retained food and sometimes swallowing cannot be achieved until the sac is full or the patient presses with his hand on the lower pharynx during the course of the meal Regurgitation of food often evil smelling may be the chief symptom and such regurgitation may be spontaneous or manually produced by firm pressure on the sac Borborygmi may be heard in the neck during swallowing and may be followed by loud eructations These symptoms may interfere with sleep often there is excessive mucus formation in the mouth In emaciated patients especially there may be serious respiratory symptoms the result of the aspiration of regurgitated food and liquid which may cause pneumonia atelectasis or lung abscess

Quite exceptionally a carcinoma may develop in the sac and equally rare is the development of a cervical infection proceeding to fistula formation But the chief complaint is a severe disturbance in swallowing

Treatment The safety of the one-stage operation has been amply proved With careful technique adequate suture in two layers and the pre and post-operative use of chemotherapy there is no longer any risk of mediastinitis and this has led to the discarding of two stage operations and of diverticulopexy The operation should always be preceded (under the same anaesthetic) by an oesophagoscopic dilatation of the crico pharyngeus muscle

Pre-operative treatment The patient should be given fluids only for a few days before operation and the sac emptied frequently by digital pressure on the left side of the neck associated with postural drainage in the head-down position frequent simple gargles and penicillin lozenges are used Parenteral penicillin is started twenty four hours before operation

The operation Preliminary oesophagoscopy will show whether the crico-pharyngeus is constricted or not if it is it should be gently dilated The mouth of the diverticulum will be inspected and its contents sucked out Intratracheal anaesthesia is then instituted and a cuffed tube employed to prevent any possible risk of intratracheal aspiration of pharyngo-oesophageal pouch contents The patient is placed in the position adopted for thyroidectomy with a small sandbag under the shoulders the neck being extended and rotated to the opposite side A collar incision as for thyroidectomy or an oblique incision along the line of the left sterno-mastoid muscle is used The anterior border of the sterno mastoid is cleared meticulously over a wide area and the carotid packet of vessels containing the common carotid artery and the internal jugular vein fully exposed ready for lateral retraction In elderly patients it is important to remember that prolonged retraction on the common carotid artery may cause permanent cerebral damage The left lobe of the thyroid is fully exposed and the middle thyroid veins doubly ligated and divided If medial retraction of the left lobe of the thyroid is not easily achieved the superior thyroid vessels are ligated and divided When the thyroid has been displaced medially and held there in a curved retractor the diverticulum is exposed beneath a layer of cervical fascia it is quite exceptional to find this adventitia of the pouch fixed to the surrounding tissues and a loose layer of areolar tissue around the pouch is easily freed by scissor and blunt pledglet

dissection The fundus of the sac should not be grasped in tissue forceps until it has been dissected completely free, because of the risk of tearing its wall, which consists almost entirely of mucous membrane which may be vulnerable Occasionally the diverticulum reaches down well into the mediastinum but can be delivered upwards with ease if the surrounding areolar tissue has been well cleared When the pouch has been isolated its junction with the pharynx is exposed meticulously It is essential to clear the angle between the neck of the diverticulum and the pharynx the pouch is then drawn laterally by traction applied through a small Duval's lung tissue forceps and the neck of the sac close to the pharyngeal wall is grasped in a Rankin or small Schumacher clamp another one is placed on the pouch which is removed by dividing the tissue flush with the clamp on the pharynx Interrupted fine linen thread sutures are then passed proximal to the clamp and left long on each side The clamp is then removed after the surrounding area of the neck has been carefully packed off with gauze swabs and the sutures are tied these sutures are closing tissue almost completely composed of mucous membrane the muscle of the pharynx is then brought over this suture line by further interrupted fine thread or silk sutures Penicillin powder is dusted over the area and the neck closed in two layers as after thyroidectomy · a small rubber drain is left in place for 48 hours

The post-operative treatment Fluids in restricted amount are allowed 12 hours after operation and there is no need for an indwelling oesophageal tube Foods such as jelly and custard are allowed on the sixth day and on the tenth day the diet may be almost normal Penicillin parenterally is given for 5 to 10 days after operation

Oesophageal diverticula

Although the oesophago-pharyngeal diverticulum of Zenker may be caused by a faulty swallowing mechanism it is not truly oesophageal The true diverticula are seen in the mid-thoracic oesophagus (Fig 19 12) and at its lower end (epiphrenal diverticulum), in both sites they are rare and neither group causes symptoms comparable with those of Zenker's pouch, though occasionally the epiphrenal diverticulum is responsible for severe dysphagia

Mid-thoracic oesophageal diverticula

" The middle segment of the oesophagus is regarded as the home of traction diverticula " (Johnstone 1949) But the writer should have added " by others " for he has produced considerable evidence that most of these diverticula are in fact pulsion in origin It has been assumed for years that tuberculous disease of the mediastinal glands may produce oesophageal adhesion and that the subsequent contraction of the fibrous tissue draws out tent-like oesophageal diverticula While it is undeniable that diverticula may be produced in this way the usual barium swallow picture of a diverticulun in this area shows anything but a " tent-like " diverticula (Fig 19 12), the fundus of the pouch being almost invariably smooth and round In fact the picture is comparable with the colon diverticulum of diverticulosis and quite different from the spiky irregular pouches seen in diverticulitis, when the pericolic inflammatory adhesions have, by their contraction, destroyed the previous smooth outline

The relatively frequent appearance of diverticula arising from the oesophagus just at the tracheal bifurcation level suggests that some at least may have a congenital origin, as this is the site of tracheo-oesophageal fistula and where slips of oesophageal muscle are attached to the trachea or bronchus If this conception is correct, the diverticula probably arise as pulsion effects in a congenitally weak area of oesophageal musculature In the rarest instance a tracheo-oesophageal fistula may develop later in life at this site, the

symptoms being the sudden onset of cough with evidence of lung infection the result of oesophageal contents passing into the respiratory tract Such an event is most commonly due to malignant disease of the bronchus but if bronchoscopy and oesophagoscopy exclude this, the type of fistula under discussion should be borne in mind for it is amenable to

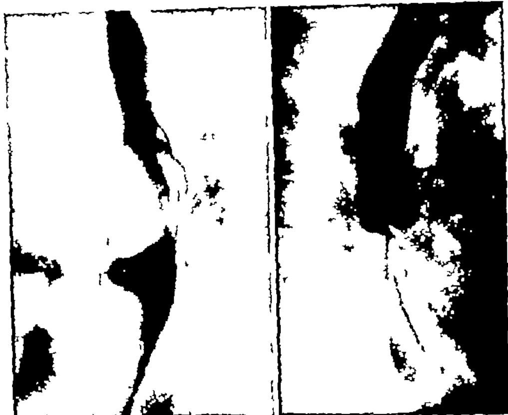


FIG 19-15 FIG 19-16

FIG 19-15 —A common site for thoracic diverticula.
There were no symptoms of dysphagia, the appearances being seen during a barium meal examination of a patient with duodenal ulcer

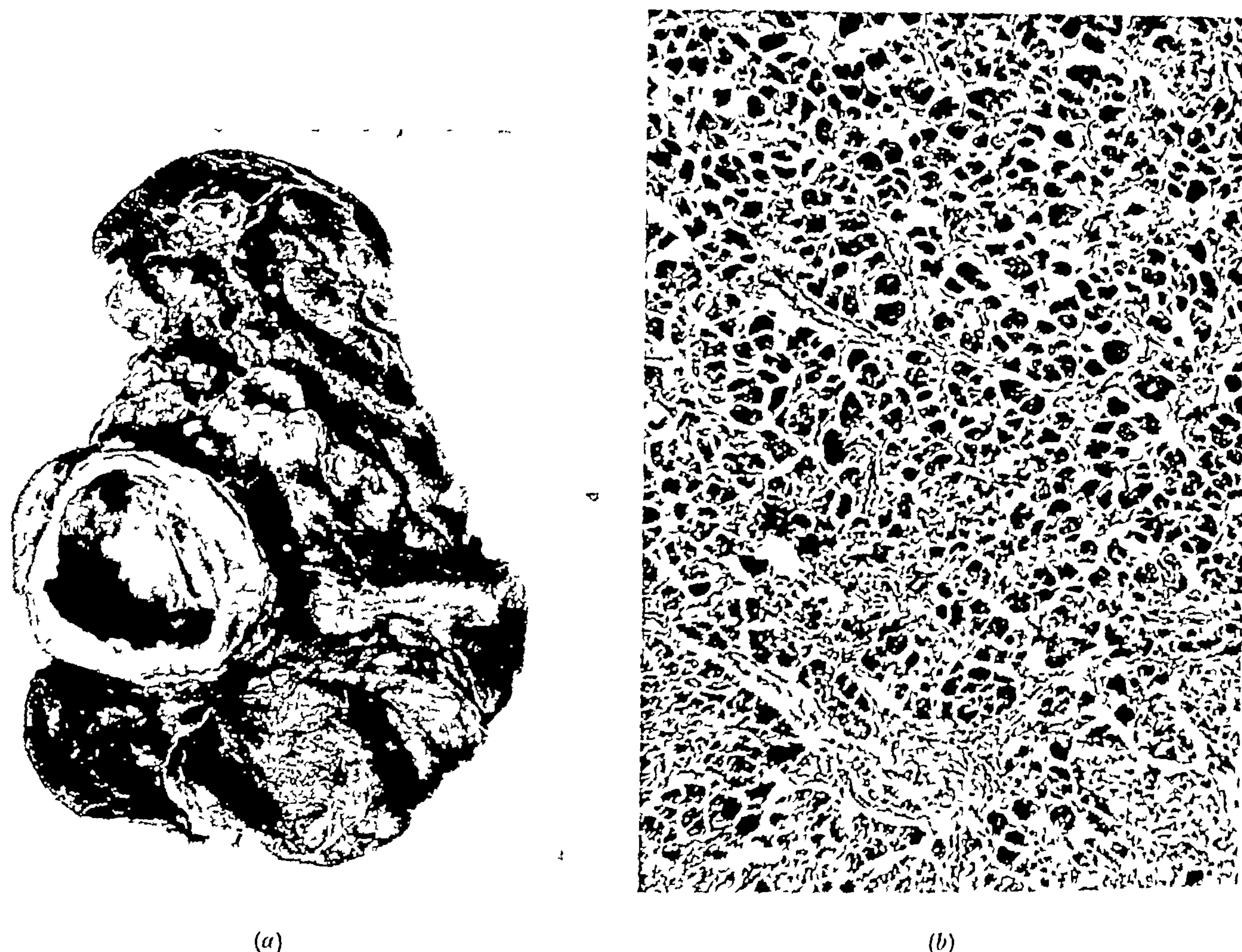
FIG 19-16 —Pseudo-diverticulum of oesophagus above a stricture due to hiatal hernia

transpleural separation with closure of the defects in the trachea and oesophagus Mid thoracic diverticula are usually symptomless being discovered during routine inspections of the oesophagus when an abdominal condition such as a suspected peptic ulcer is being investigated Mild dysphagia may be a symptom when it is present oesophagoscopy should be performed to exclude lesions such as oesophagitis which may be the causative factor of the inco-ordination of the oesophageal peristalsis Operative removal of mid thoracic diverticula is rarely indicated.

Epiphrenal diverticulum

Undoubtedly a congenital type may be found for one has been removed which contained ectopic tissue such as pancreas and was associated with an aberrant artery such as commonly supplies an ectopic or dissociated lobe of the lung (Baar and d Abreu 1949) Most of these cases, however have the appearances of an acquired pulsion diverticulum developing in elderly people with an area of weakened oesophageal wall (Fig 19 18) They may be associated with stenotic lesions of the lower end of the oesophagus though Johnstone has not seen the condition in over 200 patients suffering from cardiospasm Careful radiology will differentiate them from gastric diverticula seen in the condition of hiatus hernia

A not unusual type of false diverticulum is seen in patients with peptic oesophageal ulcer, the results of acid regurgitation when the hiatus is deficient, these are always seen



(a) (b)

Fig 19 17

(a) Operation specimen of left lower lobe and excised oesophageal diverticulum
This child had left lower lobe bronchiectasis and an oesophageal cyst the lobe and cyst were removed together The diverticulum is clearly congenital because in its wall was found pancreatic tissue

(b) Section of part of the wall of the oesophageal cyst shown in Fig 19 17 (a)
In addition to the pancreatic tissue shown here the cyst wall contained other elements of foregut tissue (Brit J Surg)

about the area of ulceration and require differentiation from the actual ulcer crater itself (Fig 19 16) In this respect they mimic the duodenal diverticula that accompany a chronic ulcer, but are sited away from the actual ulcer

Cardiospasm

This condition and spasm of the crico-pharyngeus muscle are the most satisfactory types of dysphagia to treat and once the diagnosis has been made complete relief of symptoms usually can be achieved

Function of the lower end of the oesophagus Although there is no true cardiac sphincter, the circular muscle fibres of the lower end must relax before a bolus of food passes into the stomach Normally this happens, the hiatal musculature only prevents regurgitation of stomach contents from below and plays no part at all in holding up the passage of oesophageal contents

In cardiospasm the obstruction to the passage of food into the stomach is due to spasm

of the circular muscle fibres at the lower end of the oesophagus which is itself free from intrinsic disease and from operative experience these fibres may be much hypertrophied, since the operative details are derived from a study of long-standing examples of the disease, it is impossible to know whether this hypertrophy does in fact start at an early stage of the disease but the disease has been seen to evolve in patients studied radiologically in whom the obstruction long preceded the dilatation of the oesophagus In the first stages of the disease the oesophagus above the area of spasm shows hypertrophy and strong powers of peristalsis this can be readily appreciated by *watching the passage of a barium swallow* The first few mouthfuls of barium pass into the stomach but then the bolus builds up



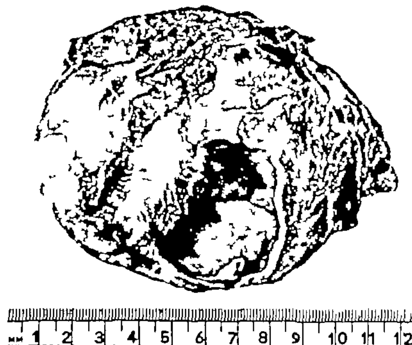


Fig 10·18 (*b*) —*Epiphrenal diverticulum after excision.*

Fig 10·18 (*a*) —Epiphrenal diverticulum in a man of 76

Severe dysphagia after a long history of minor disturbance, diverticulum excised with complete relief of symptoms.

above an area of constriction that marks the lower 2 to 3 cm of the oesophagus and violent secondary wave contractions develop from the region of the aortic notch down to the area of obstruction and often continue for as long as 45 minutes The cardia may then relax and allow the meal to pass on into the stomach.

As the disease becomes established the oesophagus steadily dilates and becomes less actively contractile the contractions first becoming weaker the nearer the fibres are to the spastic area Ultimately all peristaltic movements cease and the oesophagus becomes a huge distended tube which not only broadens but becomes longer the extra length being accommodated by the development of a bend to the right—the sigma oesophagus (Figs 10 19 10 20)

These anatomical and functional changes in the oesophagus are all secondary and not

a prelude to the spasm of the muscle in the lower few centimetres of the tube and treatment directed to them and not to the cause is futile (Barrett, 1949)

Etiology The age and sex incidence might be supposed to shed light on this, the condition is somewhat commoner in women than men Most of the patients first develop symptoms between the ages of 25–30 but it does arise rarely in children or even in infants It is said to arise in the highly nervous introspective types, this is undoubtedly true in many instances but some patients appear to be of the most phlegmatic type A sudden onset may follow emotional disturbances such as fear and fright once the condition has developed it is not surprising that changes in character become obvious and the patients



(a) (b)

Fig 19 10

(a) Radiograph illustrating cardiospasm

(b) Radiograph of a patient with cardiospasm

The oesophagus below the aortic arch has distended to an astonishing degree Note that the oesophagus above the aorta has retained its tone and has not yet dilated

Both these patients were relieved of their symptoms by Heller's operation

develop all types of mannerisms, and are shy and apprehensive when dealing with other people Whatever the original cause the fully developed state may depend on over-action of the sympathetic nervous supply to the lower end of the oesophagus and this has been supported by the experimental work of Knight, who produced the disease in dogs by sectioning the vagi but it is a curious fact that gaseous regurgitations are a common initial phenomenon in patients who have been subjected to vagotomy for peptic ulcer of the duodenum and true cardiospasm does not follow in them, although a transient obstruction is noted quite often if barium meal examinations are done early The gaseous regurgitation may be due to the pylorospasm and gastric distension that commonly follows vagotomy,

but even so the symptom should not arise if the cardiac muscle fibres were in constant spasm Chevalier Jackson's theory that the symptoms are the result of excessive activity of the diaphragmatic pinch-cock is not borne out by the condition seen at operation or by the excellent results that follow simple division of the circular muscle fibres at the lower end of the oesophagus without any alteration being produced in the pinch-cock mechanism Indeed the main function of the peri-oesophageal contraction of the crural fibres of the diaphragm is to prevent regurgitation of the contents of the stomach when that organ is distended and during the act of inspiration The disastrous results of interfering with the mechanism of the cardio-oesophageal junction and of the pinch-cock action of the diaphragm



(a) (b)

Fig 19-20

(a) A straight X ray of a grossly dilated oesophagus which extends well into the right thorax. Air can be seen above the clavicle and the sigmoid dilatation at the lower end reaches to the right cardio-phrenic angle

(b) The distended, elongated oesophagus shown in Fig 19-20 (a) is here partially outlined by a barium swallow

have been well described by Barrett and Franklin (1949) in their paper condemning the operation of oesophago-gastrostomy for the relief of cardiospasm If the mechanism is destroyed the onset of gastric reflux may cause serious oesophagitis

Nor can much attention be paid to the report of Rake in 1926 that there were histological changes in Auerbach's plexus for these are probably the sequel and not the exciting cause of the disease

The term achalasia suggested by Hurst to indicate the failure of the sphincter muscle to open is not very helpful and fails to explain the hypertrophy of the circular muscle often well seen during the course of Heller's operation

Symptoms The onset of dysphagia may be sudden and severe but more usually the patient has noticed a minor degree of difficulty in swallowing and the complaint is that food is sticking for a time at the lower end of the sternum, if meals are not taken very slowly and deliberately the difficulty becomes acute In this phase the patient often develops odd tricks such as swallowing against a closed glottis, momentary air-swallowing, or the performance of peculiar thoracic movements that force the food on into the stomach Later on the symptoms become severe so that not only solids but semi-solids and fluids pass only with great difficulty regurgitation of food into the mouth becomes a constant feature, and elements of food ingested many hours previously may be seen

Regurgitation of food at night may be followed by the aspiration of decomposed



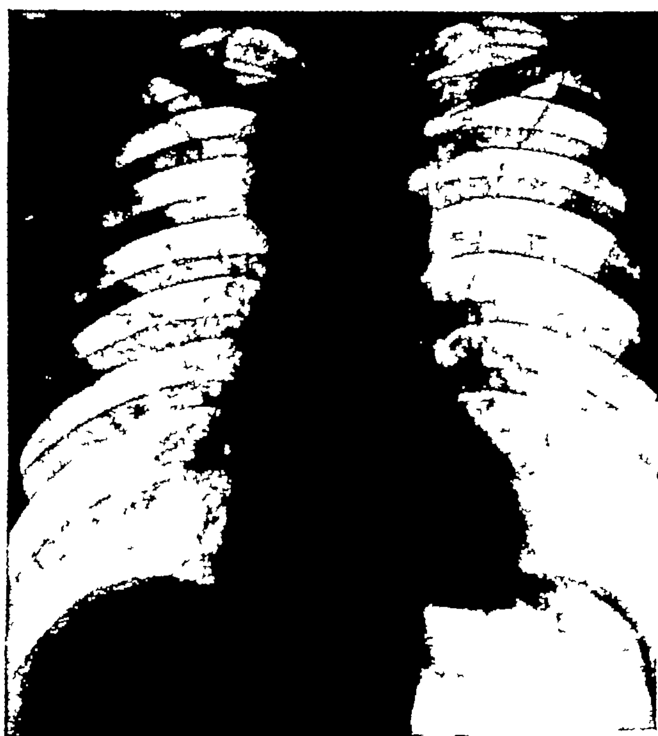


Fig 19 21 Fig 19 22

Fig. 19 21 —Illustrating a respiratory complication in a patient with cardiospasm
This woman was referred to hospital with "pneumonia" There is a segmental collapse of the left upper lobe due to the aspiration of oesophageal contents

Fig 19 22 —A plain radiograph of the chest of a patient with cardiospasm
The mediastinal "tumour" seen in the right side of the chest is due to a food filled dilated oesophagus

oesophageal contents into the bronchi, and in long-established examples of cardiospasm it is quite usual to receive a history of "pneumonia", lung abscess or bronchiectasis The radiological study of the lungs may reveal gross changes (Fig 19 21)

Atelectasis of the lower lobes may be the result of compression of the affected bronchus by the hugely distended oesophagus but is more probably the sequel of aspiration These pulmonary complications rapidly disappear after the condition has been treated efficiently Loss of morale accompanies the loss of weight and a secondary nutritional anaemia (usually not grave) may develop Many of these patients lead a solitary life, often taking their meals in companionless misery in their own bedrooms Fortunately their cure is not difficult, if too much attention is not devoted to the supposed etiological feature of psycho-neurosis which may persuade their doctors and relatives that if psychotherapy has failed nothing more can be attempted

Radiological investigation In advanced examples of the disease a plain radiograph of the chest shows an enlargement of the mediastinal shadow to the right (Figs 10 20 10 22) and at the top of this shadow a fluid level may be seen Examination of the dilated oesophagus while barium is being swallowed shows a trickle of food through the constricted lower end of the oesophagus which is too slight to prevent the rapid accumulation of the meal above it as already said in the early stages of the disease the oesophagus below the aortic notch shows active secondary waves of peristalsis As the dilatation progresses these movements disappear and a great mass of barium builds up in the inert oesophagus

Typically the constricted area produces a smooth funnel shaped appearance which



(a)



(b)

Fig 10 23

(a) Radiograph of a man of 68 years who had been assumed to suffer from cardiospasm and had been treated by mercury bougies.

(b) Operation specimen (total gastrectomy) for adeno-carcinoma of the stomach. This had involved the lower end of the oesophagus and provided the radiograph seen in Fig. 10 23 ( ) on which the erroneous diagnosis of cardiospasm had been based.

tapers off from a dilated oesophagus which is enlarged and bent over to the right (Fig 10 10) but reliance on this radiological evidence of a benign condition at the lower end of the oesophagus in a supposed early example of cardiospasm should not be accepted as this may lead to the failure to diagnose a carcinoma and oesophagoscopy is always to be advised (Fig 10 23) If the obsolete treatment of attempting dilatation by the daily use of mercury bougies is used on a diagnosis of cardiospasm made solely on radiological appearances serious mistakes may be made

Treatment The results of modern treatment are so successful that time should *not* be lost in attempting psychiatric or so-called conservative therapy Several decades in which antispasmodic drugs and the attempted dilatation of the spastic area by the daily passage of Hurst s mercury bougie have provided a mass of control cases in which clinical

cure has been unusual and these methods are truly obsolete If the constricting fibres at the lower end of the oesophagus can be ruptured safely it is not unwise to say that cure will follow in nearly all the patients, the important psychological measure is to assure the patient at the first consultation that cure will follow

The history of the treatment is interesting, it has witnessed attempts at altering the shape of the oesophagus by plication operations and by plastic operations on the oesophago-gastric junction (cardioplasty, oesophago-gastrostomy) The attack on the causative muscle hypertrophy and spasm of the muscle in the region of the cardia has been made by gentle dilatations (Hurst's mercury bougie), by forcible dilatation conducted under oesophagoscopic vision (the Russell and Negus dilator), by trans-gastric digital dilatation (Mickulicz) and by actual division of the obstructing muscle fibres (Heller's oesophago-cardio-gastromyotomy) The only two methods to survive are oesophagoscopic dilatation by the Russell or Negus bag and Heller's myotomy

The objections to the Hurst's mercury bougie are that it is messy and not curative the unhappy victim can at the best lead a modified social life and the frequent self passage of the instrument is scarcely ideal for introspective patients Operations designed to alter the shape of the distorted, distended and elongated oesophagus fail entirely to recognize or treat the cause of these changes, by-pass operations of the type seen in oesophago-gastrostomy or in cardioplasty produce in many patients a serious and sometimes fatal condition of inflammatory or ulcerative oesophagitis, following the reflux of gastric contents into the oesophagus, these pathological changes may cause severe bleeding, excruciating pain and stenosing ulceration of the oesophagus If any surgeon contemplates using any operation which destroys the oesophago-gastric function of preventing reflux of gastric contents, he should read the warnings given in an outstanding paper by Barrett and Franklin (1949) When the muscle at the lower end of the oesophagus and the upper part of the stomach is divided, as in Heller's operation, no such disagreeable effects follow, for incompetence of the oesophago-gastric junction does not result evidence of this is available from the radiological examination of many patients who have been treated by myotomy and in whom radiographs taken in the Trendelenberg position after the stomach has been filled with barium show no incompetence or regurgitation

The Mickulicz operation of trans-gastric digital dilatation is condemned by a certain riskiness inherent in the method reports of rupture of the oesophagus with fatal mediastinitis have been published and the margin between safety and satisfactory dilatation is a narrow one If the dilatation has been incomplete recurrence is the rule

Oesophagoscopic dilatation From all series of published results this provides the safest and least time-consuming form of therapy Vinson (1949) has performed the operation in 1,500 patients without a death and Allison has a large series in this country without fatality and with excellent results

The dilatation must not be blind oesophagoscopy is essential to exclude carcinoma or peptic ulceration as the cause of the dysphagia and to enable the operator to pass a special stilette through the narrowed cardia well into the stomach The dilator, which is a bag mounted on to a hollow metal container, is then threaded over the stilette until it is firmly gripped by the area of hypertrophied and over-acting muscle the bag is then gently but strongly dilatated by injecting water into it The cardia should be dilated up to four centimetres Essentials in the technique are to use a bag that will distend evenly so that it does not slip upwards during its filling and to dilate slowly Occasionally the dilatation has to be repeated

Heller's cardiomyotomy This operation has nearly 100 per cent successful result, it

is used for young patients for long-standing cases in which the great elongation and distortion of the oesophagus make the safe passage of the dilator impossible and for those patients in whom a satisfactory rupture of the muscle fibres has not been achieved It is an operation with a negligible mortality

The full division of the obstructing muscle fibres is better achieved through a thoracic than an abdominal approach A thoracotomy through the bed of the resected eighth left rib allows a rapid approach to the lower end of the oesophagus which is mobilized in the usual way (see p 440) The oesophagus and the cardia are lifted by traction on the tapes temporarily holding the oesophagus (Fig 10 24) The fascia propria and the muscle fibres are cautiously incised and then separated by a mixture of blunt and scissor dissection until the mucous membrane is clearly seen The muscle fibres are separated by scissor dissection for a distance of three inches on the oesophageal side and one inch on the gastric side of

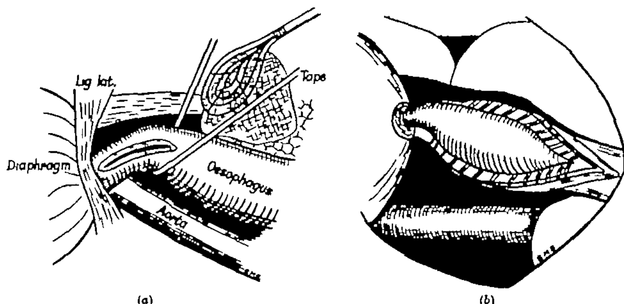


Fig 10 24 —Heller's operation.

(a) The oesophagus has been lifted up by a tape and the fully inflated lung is held away by a light retractor The incision has been started in the oesophageal muscle

(b) The incision in the muscle has been completed so that the mucous membrane is prolapsing freely

the oesophago-gastric junction several blood vessels in the muscle layer will require ligation the mucous membrane will prolapse through the longitudinal muscle incision In very long-standing cases the mucous membrane may be friable and especial care must be taken not to open it accidentally at the actual line of oesophago-gastric union I have twice opened accidentally into the mucous membrane but on each occasion a closure with fine catgut was followed by uneventful convalescence

The divided muscle incision is left widely open and the chest is closed in the usual way Drainage is not necessary but if it is dispensed with any pleural effusion detected on subsequent X ray examination will be aspirated

The post-operative course in addition to the normal management of a thoracotomy is to allow fluids at once by mouth and the patient can start taking solids on the third or fourth day The usual stay in hospital is 8 to 10 days

CARCINOMA OF THE OESOPHAGUS

Since the first successful resection of the oesophagus by Torek (1913) progress has been slow until the last decade The previous obstacles to resection of the oesophagus with

restoration of continuity have been overcome by the use of effective pre- and post-operative treatment, by efficient safe anaesthesia, and by the evolution of sound surgical techniques Although the oesophagus has no serous coat it has a thick mucous membrane which enables it to be sutured effectively to the stomach or jejunum, after these have been mobilized and delivered well up into the thorax, free from tension and with a carefully preserved blood supply The old fear that the oesophagus had a poor blood supply is no longer tenable or justified indeed it has excellent healing qualities and when a leakage does occur at the suture line between the divided oesophagus that has been stitched to the stomach or jejunum the fault lies in the latter and not in the oesophagus

The hazards of suppurative mediastinitis are avoided by careful surgical technique and the use of chemotherapy Oesophageal resection is being increasingly applied to a group of otherwise hopeless patients who suffer great misery before they die

Pathology and etiology The disease is far commoner in men than women, being in the ratio of 9 to 1 This is the opposite from post-cricoid carcinoma at the lower end of the pharynx and upper end of the oesophagus which is rarely seen in men On the whole the disease is seen in an older age group than is usual for cancer Over three-quarters of the patients are over 50 and the average age is about 65

Common sites The British Empire Cancer Campaign figures (1942) reported 52 examples in the upper third, 204 in the mid-thoracic, and 180 in the lower oesophagus. This proportion is unfortunate in the surgical sense because the tumours in the lower third are more satisfactorily dealt with than those elsewhere Many cancers at the lower end of the oesophagus are extensions of cancer of the stomach

Etiology Apart from the sharp sex difference it is difficult to assess the significance of " pre-cancerous " changes or to incriminate causative factors such as oral sepsis, swallowed irritants, or faulty diet Leucoplakia, so often seen in association with cancer of the tongue, does not seem to play a part in oesophageal cancer, in fact this epithelial change is commonly seen at oesophagoscopy for oesophagitis (see p 422), but according to Allison the patients who suffer from oesophageal ulcer with stricture formation, the result of acid-produced oesophagitis, never develop carcinoma The common association of dental sepsis in oesophageal cancer is a clinical finding that has not been subjected to sufficient statistical evaluation to establish it as a proved etiological factor In post-cricoid carcinoma the evidence is that anaemia and nutritional defects alter the state of the mucous membrane in association with spasm of the crico-pharyngeus muscle Unless these changes are relieved by iron therapy and dilatation, cancer often follows, but no such evolution is traceable in oesophageal carcinoma

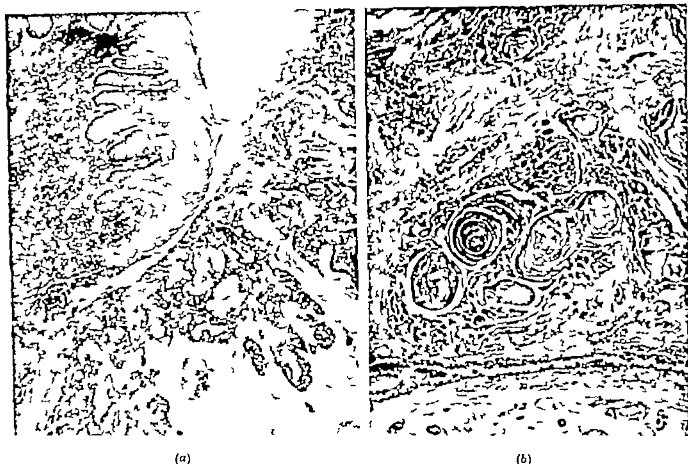
The type of carcinoma As would be expected, the true oesophageal carcinoma is of the squamous epithelioma type (epidermoid) and the histological appearances vary from the well-differentiated type of structure to the wildly anaplastic form, the latter type are naturally of a higher degree of malignancy Adeno-carcinoma may develop from the mucous oesophageal glands except in the lower third of the oesophagus, where the finding of this type of tumour on oesophagoscopic biopsy indicates a gastric cancer

The tumours may be slowly growing and exist long before they cause severe dysphagia, the extension is often around the oesophagus to produce an annular stricture and ulceration is the rule The growth may spread beneath the mucous membrane to out-crop in a different area, giving the appearance of multiple seedling tumours, and this may be apparent at oesophagoscopy More typically the tumour invades the muscle and later involves the loose peri-oesophageal tissues, the lungs the pleura, the bronchi or trachea Less frequently the pericardium, heart or aorta is invaded It is remarkable that the cancer

may produce an oesophago bronchial fistula compatible with life for several weeks though a suppurative pneumonia is usually rapidly fatal

Lymphatic spread The mediastinal lymph glands have oesophageal groups that are not regular in disposition and many nodes may be involved in the upper third of the oesophagus the lymph glands at the roots of the neck may be involved and in the lower third spread to the glands in the region of the oesophageal hiatus and along the lesser curvature of the stomach is quite frequently seen.

Symptoms and signs The growth may be well developed before real dysphagia is complained of and even with a short history the radiological and oesophagoscopic examinations may show an extensive tumour The only hope of detecting the early case is to view



(a) (b)

Fig 19 25—Histology of biopsy section removed at oesophagoscopy Squamous epithelioma of the oesophagus. (a) × 37 (b) × 1?0 (Prof J W Orr) Photograph by Dr J D Jackson.

any derangement of swallowing with real suspicion and adopt diagnostic measures at once

Once dysphagia has developed the patient frequently but by no means invariably indicates himself the site of the neoplasm This indication however is not to be relied upon when the patient points to the upper end of the sternum level for not infrequently the feeling of obstruction at this point may be due to the contractions of the crico-pharyngeous muscle or of the upper end of the oesophagus (above the aortic arch) acting on a bolus of food that is actually held up a good deal lower down Solid food creates difficulty long before liquids

The advanced symptoms include severe cachexia gross emaciation the signs of dehydration the complete inability to swallow even saliva and the onset of respiratory symptoms such as cough and sputum the sudden development of a severe choking cough

may indicate the rupture of the growth into the trachea or a bronchus with the production of a fistula

Continuous pain in the back usually indicates invasion of the posterior mediastinum and death may follow erosion of the aorta with a vast haemetemesis as the fatal terminal event Glandular involvement of the supra-clavicular glands, or rarely of the axilla, may be detected by palpation in many patients with carcinoma of the lower and middle thirds of the oesophagus, glands in the lesser omentum are involved Metastases to the liver may occasion jaundice or ascites as well as obvious hepatic enlargement Pleural effusion is a late and not common finding quite rarely too there may be a chylous, milky effusion into the thorax when the lymphatic duct has been invaded and blocked

Diagnosis. *Radiology.* This is an essential investigation but does not provide conclusive proof of carcinoma or certain evidence that a growth is not present. In spite of the usual long history of dyspepsia followed by an insidious dysphagia, peptic ulcers of the oesophagus may be diagnosed as oesophageal cancers on radiological findings. Equally perplexing may be a radiological demonstration of what appears to be a typical example of cardiospasm and yet may be in fact due to carcinoma of the upper third of the stomach (Fig 19 23) A radiological diagnosis of " carcinoma " should be confirmed by direct visualization through the oesophagoscope and a positive biopsy obtained before oesophagectomy is considered

Characteristic appearances are the loss of oesophageal contractions and a filling defect at the site of the tumour , the barium trickles through an irregular channel The gullet above the malignant stricture does not usually dilate, but if the obstruction has been present for some months, clearly will do so (Fig 19 27)

When the obstruction is at the lower end of the oesophagus the barium that escapes into the stomach may provide a filling defect characteristic of gastric carcinoma.

Oesophagoscopy Any patient with dysphagia in whom a neurological lesion or a disease of the upper respiratory or pharyngeal area has been excluded should be oesophagoscoped, however clear the radiological diagnosis of a particular lesion may appear Such an examination may alter what appeared to be an unequivocal diagnosis , as already mentioned it is particularly dangerous to rely on a radiological diagnosis of cardiospasm as the appearances may mimic those presented by a carcinoma of the cardiac portion of the stomach Leigh Collis has shown me two patients with undoubted cardiospasm who had oesophageal cancers above the area of spasm , he resected both successfully The commonest radiological error is to confuse carcinoma of the oesophagus with oesophageal ulcer, especially in elderly people Oesophagoscopy is a safe simple procedure easily performed under local anaesthesia

At oesophagoscopy three important facts require assessment

(*i*) The appearance of the tumour and its histological nature as obtained from biopsy specimens

(*ii*) The exact distance of the growth from the upper incisor teeth. In this respect it is important to remember that radiological impressions may be erroneous, often indicating an excessive length of oesophageal involvement due to areas of inactivity or spasm above and below the cancer site

(*iii*) The degree of fixity of the tumour this point may be of importance in deciding whether the tumour is operable or not If the carcinoma is in the upper or middle third of the gullet bronchoscopy should be undertaken at the same time to confirm or exclude bronchial involvement

Assessment of operability. The age of the patient is an important factor Although

men over 70 have successfully undergone resection and restoration of continuity it is unusual for patients in the eighth decade to survive this formidable operation though naturally each case must be judged on the basis of the general condition the state of the cardio-vascular and respiratory systems and of the renal function Many of these patients have advanced arthritis of the spine which adds to the risk of post-operative lung atelectasis Metastases to the supra-clavicular glands to the liver or to the lung hilum naturally indicate inoperability severe pain in the back at the site of the cancer usually indicates a spread of the tumour beyond the peri-oesophageal tissues recent cough of severity suggests



Fig 10-26



Fig 10 27

Fig 10 26—Carcinoma of the lower end of the oesophagus proved by biopsy and operation

Fig 10-27—Carcinoma of the mid thoracic oesophagus

The dilatation here this was considerable and such an appearance is not uncommon in patients with peptic ulceration and stricture.

Biopsy = squamous epithelioma.

bronchial involvement this is especially so when the cancer is sited near the left main bronchus a rather unusual but unfortunate situation as these growths are rarely resectable

Pre-operative treatment At least a week should be devoted to this it includes attention to pre-operative breathing exercises to the maintenance of adequate nutrition the correction of dehydration and the elimination of oral sepsis Solid food is completely withheld and the abandonment of the futile and irritating efforts to swallow such food often leads to a considerable improvement in the swallowing of liquid foods which should

be of a high caloric value (see p 540) Vitamins should be given in full therapeutic doses, orally and parenterally An adequate intake of iron is valuable If the fluid requirements cannot be met by swallowing, intravenous administration of glucose saline or Hartmann's solution is necessary We have been disappointed in the use of intravenous amino acids as a high proportion are excreted by the kidneys Even if anaemia is slight, blood transfusion should be employed before as well as during and after the operation Penicillin is given parenterally for 48 hours before the operation, while the sucking of antibiotic lozenges may help to decrease the infection of the ulcerated surface

A preliminary gastrostomy should be avoided as far as possible, such an artificial opening not only interferes with the technique of the operation of resection and the restoration of the alimentary canal but has a disturbing effect on the morale of the patient If artificial feeding is essential a jejunostomy has advantages over gastrostomy if the stomach and not the jejunum is to be used for the oesophageal anastomosis

Operative procedures. There are fundamental differences in the surgical approach to oesophageal resection, but in all, the first aim is the resection of the tumour-bearing area together with a wide margin of healthy tissue and the associated lymphatics, although this ideal is not always attainable At the lower end of the oesophagus the actual origin of the cancerous obstruction is often in the cardia of the stomach and the logical excision then is a total gastrectomy, a high division of the oesophagus about the level of the inferior pulmonary vein and a wide removal of lymphatic areas in the inferior mediastinum, of the lesser and greater omentum, and of all the associated gastric lymphatic glands, this necessitates the removal of the spleen and the left half of the pancreas (Allison) In spite of the magnitude of this operation the results are better than in the excision of the mid-thoracic oesophagus where the extent of lymphatic removal is necessarily limited. Frequently, however, the less radical measure of partial oesophago-gastrectomy followed by oesophago-gastrostomy is employed

The chief differences in the surgical operations employed relate to the line of approach, e g through left or right pleural cavity, and to the methods used for restoring the continuity of the alimentary tract, the aim is always to avoid a permanent gastrostomy In the earlier phases of oesophageal resection, the upper end of the divided oesophagus was artificially linked to a gastrostomy opening by means of a rubber tubing (Torek), which later was replaced by skin graft tubes and portions of the jejunum, which called for a series of difficult operations, both methods are now obsolete, the stomach or the jejunum being used for anastomosis with the divided end of the upper oesophageal segment. The disadvantage of employing the stomach, which is brought high up into the thorax, is the danger of subsequent oesophagitis and peptic ulcer, due to the reflux of gastric juice in the absence of any diaphragmatic pinch-cock mechanism For this reason the jejunum rather than the stomach may be used Technically, however, the jejunum is not available if the oesophagus has to be divided high up in the thorax and then the stomach must be used If the stomach is thoroughly mobilized it can be brought high into the thorax to the level of the clavicle

Right or left thoracotomy for the exposure Because of the ease of exposure of the oesophagus along the major portion of its length in the right pleural approach some surgeons prefer to plan their operation on the basis of right transpleural thoracotomy By opening the mediastinal pleura and dividing and ligating the azygos vein the oesophagus is easily dissected from its bed if the stomach is to be utilized for the anastomosis it can be mobilized by an abdominal approach and delivered into the right pleural cavity The drawbacks of the right transpleural approach are four.

(*a*) The abdomen must be opened by a separate incision to allow the necessary procedures for stomach mobilization to be effected it is not possible to execute the resection and anastomosis through one major incision, as it is if the left side of the chest is selected In some patients the stomach can be mobilized through the divided oesophageal hiatus from the right pleural cavity After this preliminary abdominal operation the patient s position must be altered to enable a major thoracotomy to be performed Moreover the mobilization of the stomach is more difficult through an abdominal incision than through a left thoraco-laparotomy approach.

(*b*) Operability cannot be assessed until the thorax has been explored if the condition is found to be inoperable an unnecessarily large and futile abdominal procedure has been carried out

(*c*) The stomach perhaps can be placed higher in the left pleural cavity than in the right and this is of great value when a highly placed oesophageal cancer has been resected

(*d*) The jejunum can be used for the anastomosis more readily on the left side than on the right and for many oesophageal cancers the operation of resection followed by oesophago-jejunostomy has theoretical advantages in its favour

The main objections to the use of the left sided approach are that the oesophagus is more deeply placed and partially covered by the aorta this latter objection is scarcely valid in the operable case as the oesophagus can be easily freed behind the aortic arch and if necessary brought out in front of it so that an anastomosis can be effected in front of the great vessel (ante-aortic anastomosis Fig 10 20) Many thoracic surgeons favour the left-sided approach because it is free from the main disadvantages outlined above The right-sided approach however is excellent for many mid thoracic oesophageal cancers

Resection of carcinoma at the lower end of the oesophagus *Anaesthesia* Pentothal curare and oxygen delivered through an intratracheal tube may be supplemented by small amounts of ether The use of an intratracheal tube may increase the risk of post operative pulmonary complication from a traumatic tracheitis but the control of lung inflation or deflation obtainable by this method is more reliable than that provided by a close-fitting face-mask During these long operations the lung must be kept well inflated the lung is deflated somewhat at particular phases of the operation when a diminution in its actual size is necessary for certain surgical procedures An intravenous saline drip is set up before the operation commences and blood is later substituted

The incision With the patient lying in the lateral thoracotomy position a long incision is made from the angle of the eighth rib along its length across the costal margin and well on to the abdomen to a point about one inch above and one inch to the left of the umbilicus Before the eighth rib is resected the small abdominal portion of the incision is deepened and the left rectus muscle is completely divided obliquely and often part of the right rectus The peritoneum is then opened to examine the stomach and liver so that operability can be assessed. The presence of liver metastases or gross gastric or glandular involvement does not exclude the useful palliative procedure of oesophago-jejunostomy The chief symptom the grossly distressing dysphagia can still be relieved.

If the operation whether it be radical or palliative is to proceed the eighth rib is resected sub periosteally from its angle up to and including its costal cartilage and the pleural cavity widely opened a rib retractor (Tudor Edwards or Price Thomas type) being used The lung is held upwards and medially in a large moist abdominal swab so that the triangle between the lower part of the thoracic aorta and the pericardium is clearly exposed The mediastinal pleura in this area is then incised from the diaphragm to the level of the inferior pulmonary vein and the oesophagus exposed this is cleared from its

bed, care being taken to avoid opening the right pleural cavity, unless extension of the tumour makes this a necessary planned step. A linen tape is passed round the oesophagus above the area of the growth; until this has been done or attempted, operability cannot be assessed. The growth may have invaded glands; if these are in close contact with the oesophagus itself the growth is still resectable; the same applies to involvement of glands around the inferior pulmonary veins, for these can be excised together with the loose areolar tissue of the mediastinal tunnel in which the oesophagus lies. The growth may have involved the right pleural membrane, but in certain instances part of this can be excised together with the tumour, as the intratracheal anaesthesia will maintain satisfactory pulmonary ventilation even with both pleural cavities widely opened. Extensive mediastinal involvement and spread to the aortic wall make the case inoperable; areas of involved diaphragm can be excised *en bloc* with the tumour. If it is invaded the whole oesophageal hiatal ring must be removed.

If the preliminary biopsy has revealed the tumour to be a squamous epithelioma and not an adeno-carcinoma, the oesophagus well above the tumour and the cardiac end of the stomach will be resected together with all adjacent lymphatic tissue. If the tumour is an adeno-carcinoma and arises from the cardiac end of the stomach, the correct procedure usually is total gastrectomy with a wide removal of lymphatics which may necessitate splenectomy and partial pancreatectomy (p. 541). Here it will only be necessary to outline the operation for the squamous epithelioma or certain oesophageal growths without gastric involvement.

It is wrong to think of squamous carcinoma of the lower end of the oesophagus as a lesion confined to the thorax. In many patients the tumour spreads downwards to involve the stomach and glands are frequently infiltrated along the lesser curvature of the stomach; the radical resection required is then a removal of most of the stomach and the whole of the lesser omentum followed by oesophago-gastrostomy or oesophago-jejunostomy.

Resection followed by oesophago-gastrostomy. The diaphragm is divided along a line at right angles to the combined thoraco-abdominal oblique incision down to the oesophageal hiatus. As the surgeon divides the muscle the assistant passes and ties separate thread or silk ligatures on each side of the incision; this provides careful haemostasis and the ligatures grasped separately on each side in artery forceps hold the edges of the cut diaphragm apart and so provide retraction.

The abdominal and thoracic cavities are widely explored through a single large incision. The next stage in the operation is to prepare the stomach for its high transposition into the left pleural cavity. The spleen is usually preserved but is removed if the upper two-thirds of the stomach require resection, as is often so; if splenectomy is indicated the spleen is held medially and the lienorenal ligament is incised to expose the splenic vein and artery which are divided between ligatures; the lesser sac is opened and the vasa brevia secured and divided. The vessels along the greater curvature of the stomach are isolated to the distal third of its length and tied and divided as close to the transverse colon as possible to preserve the gastro-epiploic arch. If the spleen is to be left intact the vessels in the gastro-splenic omentum are divided and ligated.

Working downward from the oesophagus the loose tissue around it, as it lies in the hiatus, is cleared and the left gastric artery divided as it leaves the coeliac axis; as much of the lesser omentum as is necessary is divided. With the stomach so mobilized and receiving its blood supply from the pyloric vessels and the right gastro-epiploic arch it can be lifted well up into the thorax. The oesophagus well above the growth is freed from surrounding mediastinal tissue with excision of as much loose tissue and lymphatic areas

as possible during this dissection if the right pleural membrane is invaded portions of it are removed

The stomach is then divided between clamps and the distal opening closed and turned in by two layers of suture interrupted thread or silk sutures or by continuous catgut on an atraumatic needle a Schumacher clamp on each side is easy to use The stomach is then placed in the mediastinum no clamps are placed on the oesophagus interrupted sutures of fine thread or silk are then passed through the muscle of the posterior wall of the oesophagus and through the sero muscular coat of the lower segment of the stomach all the stitches are placed before any are tied. It is often convenient however to remove the involved portion of stomach and oesophagus and pass the previously mentioned sutures through the oesophageal wall and the sero muscular coat of the stomach When this has been done there should be no tension evident and the approximation should be made with ease if this is not so the stomach has not been mobilized adequately If still attached the stomach is then incised along the proposed site of the stoma each bleeding vessel is seized in fine artery forceps and tied Any remaining fluid in the stomach is removed by the aspirator The oesophagus is then opened below the previously placed posterior wall suture and the area of growth and upper portion of the stomach removed after a posterior layer of suture has been placed This step is easier if the oesophagus has been cut across completely before any suturing has been started Interrupted silk or thread sutures are passed through all layers of the posterior wall of the oesophagus and those of the gastric stoma on the oesophageal side chief reliance in the anastomosing process will be placed on those stitches that hold the stout oesophageal mucosa Again all stitches are passed before any are tied. The anterior layer is then completed and reinforced by interrupted sutures through the fascia propria and muscle wall of the oesophagus and the gastric serosa

The essence of safety lies in securing an anastomosis quite free from tension and to obtain this the mobilization of the stomach must have been satisfactory It may be sometimes necessary to mobilize the peritoneum on the outer side of the duodenum

The whole anastomosis is then steadied by a few interrupted sutures anchoring it to the parietal pleura in doing this it is important to avoid placing the stitches over the serosa covering the aorta. In one of my patients an ulcer developed in the stomach at the site of such a suture and caused a fatal haemorrhage six weeks later

A pedicled pleural flap fashioned from the parietal pleura is wrapped round the anastomosis to which it is secured by a few interrupted sutures

The diaphragm is then closed a few interrupted sutures being placed to unite it to the stomach wall Penicillin powder is insufflated over the anastomosis area and the chest and abdominal wall closed in layers according to the usual technique

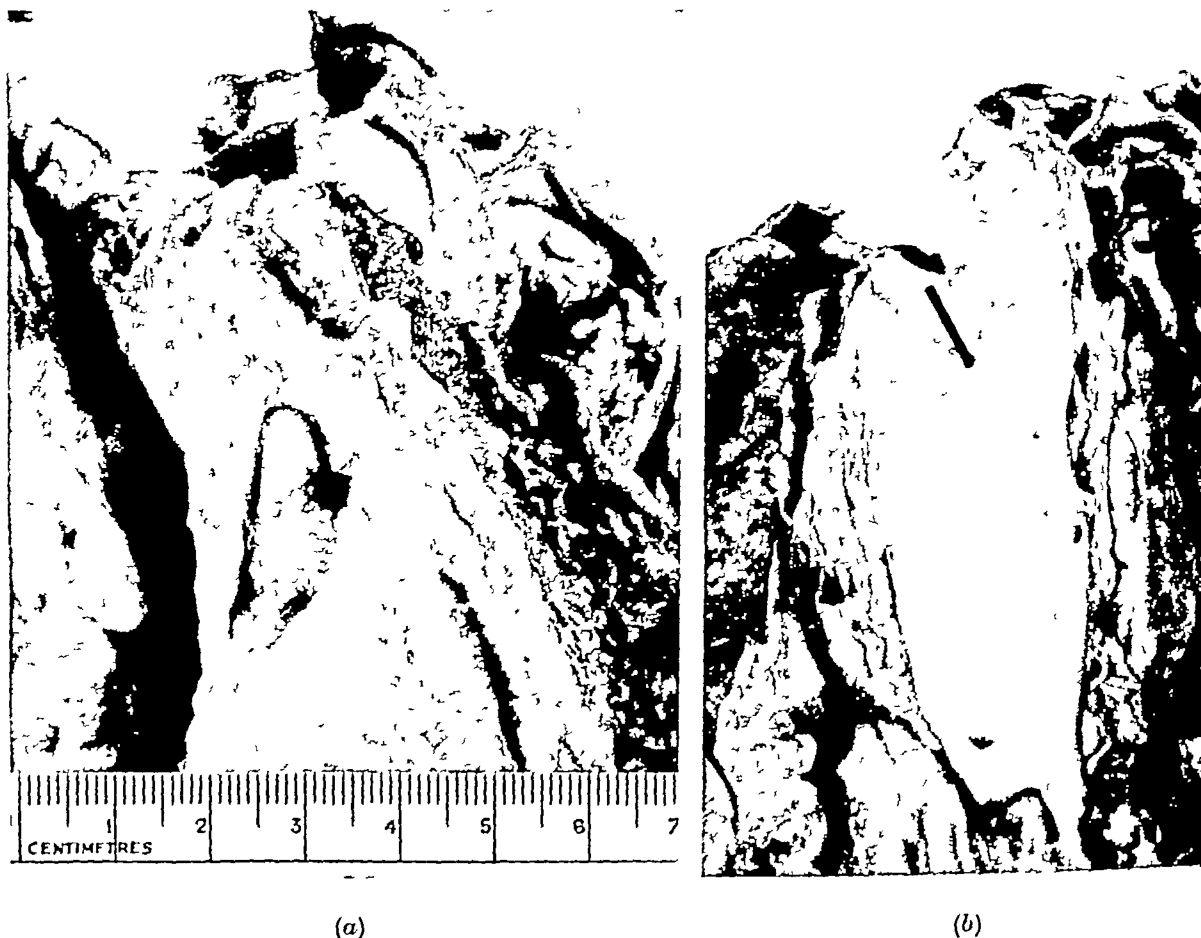
An intercostal drain is placed close to the anastomosis and the lung is fully re-expanded at the close of the operation The tube is retained for 24 hours and the lung and pleural state estimated by portable X ray photographs The care of post-operative lung collapse and of pleural effusion is along the usual lines At the close of the operation the oesophagus and tracheal tube should be thoroughly aspirated under direct vision through the oesophagoscope and bronchoscope

Post-operative management This follows the routine indicated on page 34o for total gastrectomy and guided by the principles discussed in Chapter 5

Resection followed by oesophago-jejunostomy The use of the stomach for the performance of the anastomosis has the advantages of greater simplicity and greater ease in execution physiologically it allows the swallowed food to have the undoubted advantage of gastric digestion before passing on into the small intestine Its chief disadvantage is

that it leaves the patient without any physiological sphincter and undoubtedly the regurgitation of acid into the oesophagus can produce oesophagitis and peptic ulceration in some of the patients, especially those in the younger age group For this reason oesophago-jejunostomy has some advantages its main disadvantage is that it may be followed by severe diarrhoea and malnutrition (Brain, 1951) The operation of oesophago-jejunostomy whether as a palliative short-circuiting procedure or as part of a radical resection is described on page 424

Operation for growths of the mid-thoracic oesophagus. These are less satisfactory than for carcinoma in the lower oesophagus and the results are not so good, probably



(a) (b)

Fig 19 28

(a) Ulcer in the stomach after oesophagectomy, followed by oesophago gastrostomy This produced a fatal perforation into the aorta
(b) The pointer in the eroded part of the aorta

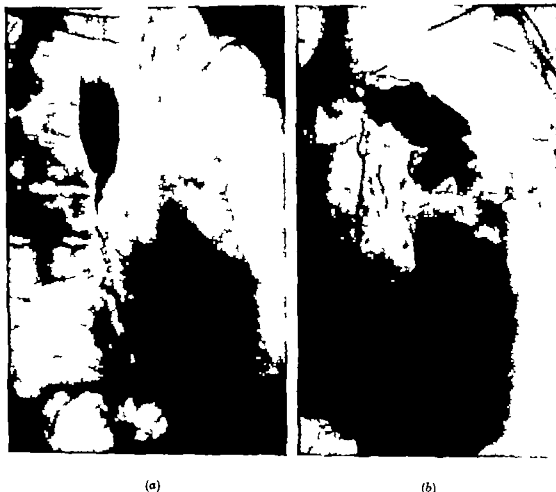
because of the rapidity of glandular involvement and the difficulty of securing a really radical excision.

If the growth is well below the aortic arch the procedure as described for growths of the lower end can be employed If, however, the tumour is so situated that a satisfactory excision is not possible below the aortic arch, the divided and freed oesophagus must be cleared up to the arch itself, the parietal pleura above the aortic arch is freely divided, a tape or tapes placed around the aortic arch, which is then lifted upwards from the oesophagus It is safer to dissect the aorta off the oesophagus than to attempt the reverse process (Allison) Vessels coming off the aorta itself are ligated and divided, including those supplying the oesophagus and possibly the bronchial arteries The oesophagus is

then delivered above the arch of the aorta in front of which the anastomosis is made (ante-aortic anastomosis) For this procedure it is essential to have a very full mobilization of the stomach but usually it can be delivered quite readily up to the level of the clavicle

The surgical exposure for this high anastomosis may be inadequate through the eighth rib thoracotomy a further exposure may be obtained by a resection of the fifth rib in its entire length and a second thoracotomy made through its bed Alternatively the back ends of the seventh sixth and fifth ribs may be shingled

Carcinoma of the mid thoracic oesophagus can well be treated through a right thoracotomy incision the stomach must be mobilized by an abdominal operation in the way already



(a) (b)

Fig 10-20 —Radiograph after ante-aortic anastomosis following excision of carcinoma of the mid thoracic oesophagus.
(a) Before operation.
(b) After operation.

described through the left thoraco laparotomy incision After the laparotomy incision has been closed the patient is placed on the left side and a right thoracotomy performed through the bed of the resected fifth rib

The oesophagus is then mobilized and is easily accessible in the upper part of this dissection the azygos vein is doubly ligated and divided

The stomach is then drawn up through the oesophageal hiatus and a high anastomosis is easily obtained (Fig 10 30)

Palliative treatment for inoperable carcinoma of the oesophagus If resection followed by oesophago-gastrostomy or oesophago jejunostomy is not possible because of



Fig 19 30 —Radiograph of the chest a year after excision of the oesophagus for carcinoma
The stomach has been anastomosed to the cervical oesophagus through a right thoracic approach

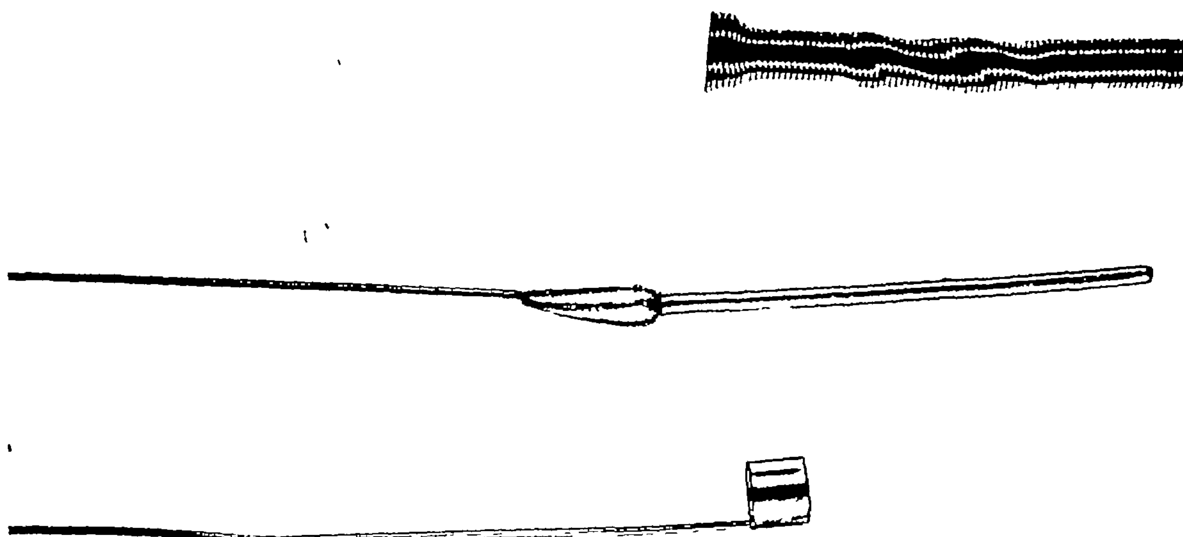


Fig 19 31 —Souttar's tube with the two introducing instruments
These are readily inserted under direct vision through an oesophagoscope

the general or local state of the patient gastrostomy should be avoided as long as possible Apart from the misery of this condition most of the patients do not survive their stay in hospital The most satisfactory relief is produced by Souttar's tube which is placed in the area of stenosis through the oesophagoscope by this means fluid and even solids can be swallowed and this relieves the worst feature of oesophageal obstruction namely thirst The palliation it provides may enable the patient to obtain reasonable comfort for two to six months *

Radiotherapy is of undoubted value in some patients The disappearance of the tumour mass may be followed by a cicatricial fibrosis and at all stages no hesitation should be felt about repeating the oesophagoscopy and dilating such strictures or canalizing them by a Souttar's tube (see Fig 10 31)

BENIGN TUMOURS OF THE OESOPHAGUS

These are unusual and arise from the mucous membrane as pedunculated masses (papilloma) or from the wall of the oesophagus itself (lipoma fibroma leiomyoma) The commonest tumour is the leiomyoma which is seen in the middle or lower portion of the gullet It is an encapsulated tumour that does not penetrate the mucous membrane but spreads up and down or around the oesophagus dysphagia of a severe type is more common in the latter group whereas the ovoid elongated mass tends to produce a feeling of fullness behind the sternum rather than actual difficulty in swallowing The history is a longer one than seen in patients with carcinoma the barium swallow shows an area of defective filling or complete obstruction when the mass has encircled the oesophagus because of the slow growing rate of these tumours the gullet also may be dilated Oesophagoscopy reveals the bulging in of an intact mucous membrane

The tumours are resected through a thoracotomy incision the involved area of the oesophagus is fully exposed before it is mobilized and lifted out by an encircling piece of linen tape An incision is then made through the muscle overlying the tumour which can be shelled out often without any opening being made into the lumen of the gullet The oesophageal wall is closed in two layers with fine interrupted silk or thread sutures and the chest temporarily drained by a water sealed intercostal tube

In the unusual type which has a pedunculated base with prolapse of the tumour into the lumen the oesophagus is deliberately opened and the tumour removed the mucous membrane is then carefully closed by interrupted sutures The same method is used for innocent tumours such as the large papilloma which grows from the mucosa

TRACHEO OESOPHAGEAL AND BRONCHO OESOPHAGEAL FISTULAE

(Non-congenital)

Malignant disease

The commonest cause of acquired tracheo or broncho-oesophageal fistulae is malignant disease usually of the lung sometimes of the oesophagus and rarely of the trachea The combination of oesophageal symptoms with those of the lung should soon lead to detection

* I have two patients who are alive and in reasonable comfort 18 months after the palliative use of Souttar's tube both were patients with squamous epithelioma of the oesophagus proved by histological examination of biopsy material

of the cause by clinical, radiological and endoscopic examinations. Quite exceptionally the diagnosis may be dramatic when during the course of a barium swallow examination of the oesophagus the opaque meal is seen to flood the bronchial tree under the viewing screen

The treatment of such malignant fistulae can only be symptomatic gastrostomy is rarely justifiable though in one patient who had been known to have an inoperable bronchial carcinoma for a year, three months' satisfactory relief from constant choking was provided by this method Dysphagia in malignant disease of the lung is more often due to glandular involvement than to spread of the tumour to the oesophagus

A malignant tracheo-oesophageal fistula may occasionally be amenable to Wookey's operation in which the larynx and lower part of the pharynx are resected a permanent tracheotomy is, of course, essential but the pharyngeal defect can be closed by plastic operations

Acquired non-malignant fistula (oesophago-bronchial)

(*a*) *Acute inflammatory conditions as the cause* Extremely rarely a pyogenic pleural empyema may rupture into the oesophagus actinomycosis may produce such a communication The previous pleuro-pulmonary symptoms will be complicated by choking, especially during the swallowing of food or liquids, or occasionally the vomiting of pus The investigation of such symptoms should be by a lipiodol swallow examination and by oesophagoscopy the treatment essentially is adequate drainage of the empyema In patients suffering from actinomycosis, penicillin therapy combined with sulphonamides and iodine should be followed by a prolonged course of carefully graduated doses of deep X-rays

(*b*) *Chronic inflammation* A few patients have been recorded in whom the fistula resulted from the ulceration of impacted foreign bodies Although tuberculous disease of the oesophagus is almost non-existent, calcified tuberculous glands may ulcerate later into an air passage and the oesophagus with a resultant broncho-oesophageal fistula These patients may have coughed up and vomited calcareous masses the symptoms of choking and cough indicate the need for radiological examination after the swallowing of lipiodol Sometimes bronchiectasis of a lobe may be associated with the fistula I have seen this in the cases of middle lobe bronchiectasis associated with one of these fistulae After the middle lobe had been removed, the opening into the oesophagus was easily closed in two layers after its edges had been excised

Occasionally a fistula is discovered in an adult near where congenital tracheo-oesophageal communications occur. At operation for the closure of these abnormal connections, after the oesophagus has been well cleared above and below the area of the fistula, its actual track, which is usually short and of narrow calibre, may appear to be singularly free from evidence of inflammation The tracheal and oesophageal openings are closed by interrupted thread or silk sutures and attached pleural flaps sutured over the raw edges

Perforations and tears of the oesophagus

These may be due to trauma (penetrating wounds or as the result of an accident during oesophagoscopy), to spontaneous perforation of the lower third of the tube, to rupture of a peptic oesophageal ulcer, to post-operative leakage after oesophago-gastrostomy or oesophago-jejunostomy to neoplastic processes of the oesophagus itself or of the bronchus, as a sequel to pleural empyema or as the result of tracheo-oesophageal fistulae (other than the congenital type seen in new-born infants) Though unusual they present important

and difficult diagnostic problems apart from the group due to malignant disease they are amenable to surgical treatment

(*a*) *Traumatic laceration* The accidental perforation of the posterior pharyngeal wall or of the thoracic oesophagus during oesophagoscopy is more readily recognizable than the other varieties because the accident is probably obvious at the moment of its infliction or because the serious symptoms and signs of perforation will be apparent in a few hours time while the patient is still under hospital care Pain pyrexia subcutaneous emphysema and pneumothorax after oesophagoscopy will indicate the need for immediate exploration of the neck or thorax (see p 58) Immediate suture in two layers the management of any complicating pneumothorax and the use of antibiotics should be followed by survival if the catastrophe is recognized early

In gunshot or stab wounds exploration of the thorax is indicated unfortunately the oesophageal wound is usually overlooked in the early stages when attention is being directed to the correction of the physiological derangements that often follow thoracic trauma Perhaps the most important signposts are provided by the development of surgical emphysema above the clavicle difficulty in swallowing pleural pain and the rapid accumulation of fluid in the chest which on aspiration clearly consists of the liquids that have been swallowed. In warfare most of the noted cases have been detected during the course of a formal thoracotomy for severe intrathoracic injuries or later when an empyema has developed which after drainage discloses oesophageal contents

Remarkable findings may be recorded In one patient a stab wound of the left supraclavicular fossa was followed by the rapid accumulation of fluid in the left chest the aspiration of this withdrew large quantities of milk which the patient had swallowed after the attack In another patient a small revolver fired at point-blank range into the right supraclavicular passed across the mid line and the bullet was easily palpable in the left axilla immediate difficulty in swallowing and breathing followed At oesophagoscopy and bronchoscopy the posterior wall of the trachea just above the bifurcation showed bruising and oedema but the oesophagus appeared quite intact fluids were withheld for three days and apart from a small right-sided haemothorax which required aspiration the patient made a complete recovery A traumatic perforation of the oesophagus into an empyema cavity due to a foreign body lodged in the body of the seventh thoracic vertebra was seen in another patient five days after wounding

In traumatic lacerations the oesophagus should be approached from the right side for wounds of the mid thoracic region from the left if in the lower three inches the laceration is sutured in two layers with interrupted sutures and the pleural cavity drained by water sealed drainage

(*b*) *Spontaneous perforation of the oesophagus* There seems no doubt that the normal oesophagus can tear in its lower third after the swallowing of large amounts of food or of great quantities of fluid The tears are longitudinal and may have the appearance of a clear incised wound the absence of disease in the oesophagus may lead to the condition being overlooked even at post mortem examination Barrett (1940) has provided a classical description of the pathological and clinical features of this rare condition he points out that surgical cure by immediate suture of the laceration is only possible if the profession is aware of the fact that the accident does happen that it has a definite symptomatology and can be diagnosed

Pathology and etiology Usually the tear is from 1 to 8 cm in length in the left postero lateral aspect of the lower end of the oesophagus above the diaphragm there being only two recorded instances in which the site was different (in one the tear ran on into the

stomach and in the other it was at the level of the tracheal bifurcation). The rupture may be small and overlooked at autopsy unless the oesophagus is tied off below the area involved and then filled with fluid from above If the tear is higher than usual the right pleural cavity will take the oesophageal contents and in the rare instances of transverse tearing both pleural cavities may be swamped

The lower end of the oesophagus is the weakest part of the tube and when it tears spontaneously the rupture will usually be in that area which is covered only by the parietal pleura of the left side without the cushioning support of the aorta and the retro-pericardial fat

The swallowing of large meals, the intake of vast quantities of fluid, especially if alcoholic, and violent retching and vomiting are etiological factors of great importance in most of the recorded cases Barrett believes that alcohol, by preventing the necessary co-ordinated movements in the act of swallowing and the vomiting, plays an important etiological part Further evidence of the danger of impeded vomiting is presented by Barrett when he analyses the ruptures that have developed below areas of oesophageal strictures in patients who have been retching violently In most of the reported histories he found accounts of violent vomiting often associated with "gluttony and alcoholism"

Signs and symptoms The onset is sudden, dramatic and catastrophic Although vomiting may have preceded the development of sudden agonizing pain in the upper abdomen, behind the lower end of the sternum and in the base of the chest with possible referred phrenic nerve pain to the shoulders, it ceases to dominate the clinical picture as soon as the disaster has occurred The pain is even more intense than that associated with rupture of a peptic ulcer of the stomach and duodenum, with which the diagnosis is most often confused It remains quite unrelieved by morphia Cyanosis and grunting respirations are noted at the outset and the pulse rate accelerates far earlier than in the typical perforated gastric or duodenal ulcer the upper abdomen shows board-like rigidity and is extremely tender, an added reason for the diagnosis of perforated peptic ulcer being made

Unfortunately the chest signs, in the absence of a radiograph, are in the early stages not obvious in most patients, though occasionally of such magnitude that they dominate the clinical picture decreased movements and the discovery of râles in the bases are not unknown in perforated gastric ulcer or acute pancreatitis If, however, in the diagnosis of normal upper abdominal catastrophes, a radiographic examination were made with the patient in the upright position a fluid level due to a hydro-pneumothorax would at once establish the diagnosis, which could be confirmed by the withdrawal of gastric contents, possibly blood-stained, by thoracentesis

In a few patients surgical emphysema in the neck may indicate the rupture of the oesophagus into the posterior mediastinum, but such a sign is unlikely to be an early one

The logical surgical treatment is by thoracotomy, suture of the tear, a careful clearing of the pleural cavity and closed drainage of the chest

The condition is rare but should be borne in mind in patients with the signs and symptoms of an upper abdominal catastrophe, especially when this takes place after large meals or bouts of drinking I have seen three, two were diagnosed and one was subjected to a laparotomy on the basis of a pre-operative diagnosis of perforated peptic ulcer, he died the next day and the true state of affairs was seen at autopsy Of the other two one survived after thoracotomy gastrostomy and drainage and the other died ten days after

the catastrophe he had been treated by gastrostomy and pleural drainage Undoubtedly Barrett s advice that survival will best follow thoracotomy and repair of the laceration, is correct

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CHAPTER 20

MEDIASTINAL TUMOURS

It is as awkward to classify these tumours as to outline the symptoms they may produce some of the "tumours" seen may be cysts and not neoplasms, remaining symptomless unless complications, such as thoracic compression, become evident Malignant tumours, usually extensions from bronchiogenic cancer, may cause the gravest symptoms, usually of superior mediastinal compression associated with gross dyspnoea and swelling of the face and hands Although the commonest tumour of the mediastinum is invasion by bronchial carcinoma and the next commonest that of lymphadenoma (Hodgkin's disease), the diagnosis of these two conditions, which can only be treated by radiotherapy, must not be made lightly, for their symptoms and radiological appearances can imitate those of curable conditions such as intrathoracic goitre or mediastinal cysts (dermoid, bronchogenic or enterogenous)

A convenient classification of mediastinal tumours includes cysts which are not properly neoplastic and this listing will be followed here A division of these tumours into simple and malignant is not as logical as might be supposed, for apart from certain types of cysts, some of the innocent tumours are potentially malignant As an example may be mentioned the malignant degeneration of the neurofibroma, a tumour sometimes alleged to be of no danger unless causing compression symptoms, Brian Blades (1941), surveying the world literature on the subject, estimated that 41 per cent of these tumours underwent sarcomatous change For this reason a classification based on the regional distribution of mediastinal tumours and cysts is more useful and the one given below is based largely on a paper by Brian Blades (1941), and from the studies of Heuer and Andrus (1946) on 230 examples

ANTERIOR MEDIASTINAL TUMOURS

1. *Carcinoma* (usually secondary to bronchial carcinoma) Rarely may arise in epithelial tissue in the thymus gland
2 *Tumours of lymphatic origin.*
   (*a*) Hodgkin's disease Lymphoma
   (*b*) Lymphosarcoma
   (*c*) Thymoma and thymic enlargements
3 *Thoracic goitres*
4 *Dermoids and teratomata* *
5 *Pericardial cysts or pleural cysts* ("The spring-water cysts")

POSTERIOR MEDIASTINAL TUMOURS

1 *Carcinoma* (secondary to bronchial carcinoma)
2 *Neurofibroma* (usually posteriorly sited, though rarely placed elsewhere in the line of an intercostal nerve and exceptionally in the anterior mediastinum)
3 *Bronchiogenic and enterogenous or gastrogenous cysts* (usually found in the right posterior mediastinum, but occasionally on the left side and anteriorly)

TUMOURS ARISING ANYWHERE IN THE MEDIASTINUM.

1 Lipoma
2 Fibroma—fibro-sarcoma
3 Zanthoma
4 Chondroma
5 Hydatid cysts (almost invariably secondary to hydatid disease of the lung)
6 Lymphangioma

* *In two of my patients, one a dermoid cyst and the other a malignant solid teratoma, the tumours were placed in the posterior mediastinum*

General aspects

The symptoms of mediastinal tumour (when symptoms are present) depend on the size rate of growth character and position of the mass The size of the tumour may bear no relation to the symptoms a small one pressing on the bronchus with resultant atelectasis of a lobe or a lung may cause severe distress while a large posteriorly sited neurofibroma may be silent Pressure effects may produce dyspnoea with stridor and this arises most commonly from a retro-sternal goitre but other tumours in the superior mediastinum may be responsible Dysphagia usually develops much later than dyspnoea being not uncommon when the mediastinum is invaded by bronchiogenic carcinoma Pain may be caused by local pressure or by a secondary pleuritic reaction due to infection in a collapsed area of lung the result of bronchial occlusion

Engorgement of the venous trunks draining the head and arms is a feature indicating a late diagnosis and an advanced degree of intrathoracic pressure the face and arms may show a dusky cyanosis and an oedema that is worse on waking in the morning The usual cause of such obstruction is a secondary malignant spread from bronchial cancer but this should not be assumed without full investigation for the engorgement may accompany a removable innocent tumour of an intrathoracic goitre rarely it is due to thrombosis of the superior vena cava (Tubbs 1946)

Thrombosis of the superior vena cava

Because of the diagnostic problem a brief note on this rare condition is included here The vein may become clotted in the condition associated with phlebo thrombosis developing else where and malignant disease may be an important factor About one quarter of the patients have a curious fibrotic infiltration of the superior mediastinum the etiology of this was ascribed by Ochsner and Dixon (1936) as being due to syphilis in 11 and tuberculosis in 10 in a series of 28 examples of this condition The etiology remained obscure in 7

In one of three patients with this condition under my care the histological appearance resembled that seen in examples of Riedel s ligneous thyroiditis

Clinically these patients present the classical features of superior vena cava obstruction of slow onset swelling of the upper limbs is unusual. A full examination fails to reveal any obstructive cause such as carcinoma of the lung aneurysm or mediastinal tumour There is *no effective* treatment and surgery is contra indicated A collateral circulation develops and patients have survived for many years.

Mediastinal tumours by pressure on nerves may cause intercostal pain and this is one of several reasons for avoiding the misleading diagnosis of pleurodynia or *intercostal* neuralgia diaphragmatic irritation with phrenic nerve pain referred to the *shoulder* tip or diaphragmatic paralysis may follow pressure from a mediastinal tumour innocent or malignant

The sympathetic nervous chain may be irritated by pressure or paralysed by *infiltra* tion sweating of one side of the face pupil changes and enophthalmos may be *seen* There may be symptoms attributable to pressure upon the vagus nerve and I have removed mediastinal tumours from three patients with symptoms suggestive of duodenal ulcer in one instance the tumour was a large posteriorly placed bronchiogenic cyst and in the other two a posterior neurofibroma was excised the alimentary symptoms were relieved in two but the third *had* a duodenal ulcer later successfully treated by partial gastrectomy Pressure on the recurrent laryngeal *nerve* may involve voice changes

Quite exceptionally the tumour may be gross enough to produce actual bulging of the chest wall (Fig 20 17) associated usually with extreme displacement of the apex beat of the heart Severe displacement of the heart may cause serious symptoms

Tumours of the thymus may be associated with myasthenia gravis

Physical signs. These will depend entirely on the size and effects of the tumour. The tumour mass may produce an increase in dullness on percussion, engorgement of veins and the nerve palsies referred to above may be noted If atelectasis of a lobe or lung is present, the appropriate signs will be detected, but the main features detectable are radiological ones

Radiological appearance of mediastinal tumours. This is the essential diagnostic weapon and many conditions can be labelled accurately from the radiological characteristics Screening is essential as the whole thoracic anatomy and movement require study the radiological appearances may be confined to the delineation of the tumour alone or include secondary appearances such as atelectasis Perhaps the most difficult examples

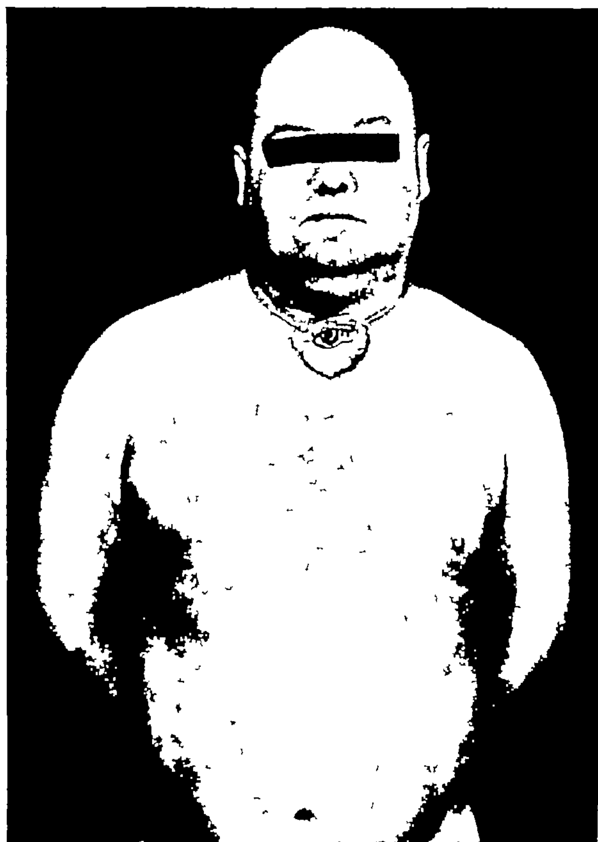


FIG 20 1—Photograph of a man of 56 with superior vena caval obstruction due to inflammatory superior mediastinitis

The dense fibrosing process, which is not unlike the appearances seen in Riedel's woody thyroiditis involved the recurrent laryngeal nerves a tracheotomy was essential seven years ago The radiograph of the chest at the time of the photograph shown above revealed no abnormality

Patient of the late Prof K D Wilkinson and Mr Stirk Adams)

presented for diagnosis are when much of the mediastinal shadow is enlarged as the differentiation of secondary carcinoma, of Hodgkin s disease, of malignant tumour, or simple enlargement of the thymus, aneurysm and retro-sternal goitre may be difficult on radiological appearances only Occasionally a faulty diagnosis of pericardial effusion, cardiac enlargement or cardiac aneurysm is made It is important to realize that many innocent mediastinal tumours show transmitted pulsation on X-ray screening whereas a considerable number of thick-walled aortic aneurysms full of laminated blood clot show no expansile pulsation at all and it is unwise to diagnose a thoracic aneurysm entirely on the results of screening

Shadows that overlie the heart and aorta are indeed most difficult to assess and require

the careful "all round the heart" screening and the added aid of a barium swallow (Fig 20 33) Angiocardiography may establish the extravascular site of the mass (Sussman 1947 O A. Abbott and others 1949)

Although apparently encapsulated circular or ovoid shadows in the lung fields are often malignant but this is not so in the case of mediastinal tumours and the clear-cut edges and outlines of neurofibroma dermoid and other cysts and retro sternal goitre are fairly reliable indications of their innocent nature

These edges tend to be blurred and indistinct when malignant change has taken place (e g malignant neuroblastoma in children)

The location of the tumours is important retro-sternal goitres and mediastinal dermoid cysts are usually sited anteriorly and the shadow cast by an intrathoracic goitre is often typical It is important however to remember that this is not always so and the goitre may be in a posterior mediastinal position behind the oesophagus (Tomkinson 1951)

Again the neurofibroma is usually recognized by its ovoid shape consistent density and its location in the posterior mediastinum It is not always possible to differentiate this from such conditions as bronchial or enterogenous cysts placed in the posterior mediastinum

The use of diagnostic artificial pneumothorax The need to differentiate an intra or extrapulmonary site of a tumour by taking radiographs after a diagnostic artificial pneumothorax has been blunted by the generally accepted principle that ovoid or circular intrathoracic tumours call for thoracotomy but the method may provide occasional information of value Barrett (1949) makes the interesting observation that in patients with thin walled fluid-containing cysts of the superior and pre-pericardial areas ("spring water cysts" see p 481) the peculiar laxity of these cysts is such that an artificial pneumothorax alters their shape and density and so is of diagnostic value

ANTERIOR MEDIASTINAL TUMOURS

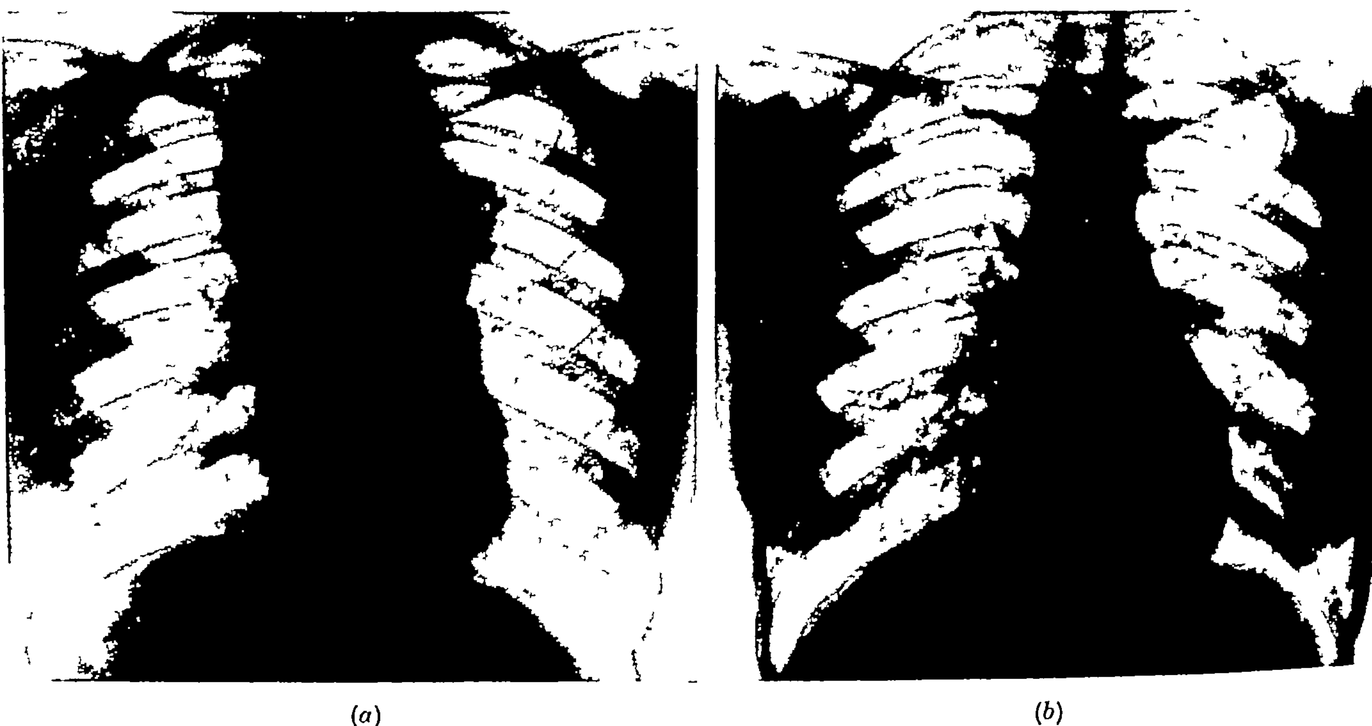
Carcinoma

Apart from the rare development of cancer in thymic tissue this condition is secondary to a bronchial carcinoma The mediastinal involvement may be gross even when the primary lung tumour is small or insignificant The condition was frequently diagnosed in earlier days as "mediastinal lymphosarcoma" The oat-celled carcinoma is the usual neoplasm and the spread may be rapid Less commonly the original tumour is in the oesophagus or rarely the trachea

Clinical features Cough may not be a notable symptom but its presence with the association of haemoptysis is an important clue to the correct diagnosis and the other symptoms of bronchial carcinoma may be present The mediastinal involvement may produce swelling and vascular engorgement of the face and arms often with dilatation of the veins of the neck and upper extremities frequently worse when the patient awakes in the morning Hoarseness due to the involvement of the recurrent laryngeal nerve is common dyspnoea and later dysphagia indicate the degree of superior mediastinal pressure present but the difficulty in breathing may be associated with a blood-stained pleural effusion or atelectasis of a lung or a lobe of a lung the result of actual blockage of the bronchus by tumour or by the encirclement of the bronchus by enlarged glands Each of these symptoms may produce characteristic physical signs The supraclavicular glands may be enlarged. The diagnosis will depend largely on radiological examination If an area of lung atelectasis is associated with a great invasion of the superior mediastinum the diagnosis of bronchial

carcinoma can often be confirmed by bronchoscopy , quite exceptionally these conditions may be seen with retro-sternal goitre, though atelectasis is rare in that disease, however severely distorted the trachea may be

Differential diagnosis Many of these cases were regarded in the past as lymphosarcoma, but this condition is rare and the diagnosis is rarely acceptable on clinical or radiological grounds in the absence of histological proof The involvement of the superior mediastinum in lymphadenoma is, however, common and in all examples of clinical thoracic compression of the superior mediastinum it is to be considered , chief difficulties will be encountered when the first lymphadenopathy to develop is in this region , typically, however, the presence of enlarged lymphatic glands in the posterior triangles of the neck, abdomen, axillae, and groin co-exist and the liver and spleen may be enlarged The diagnosis will be confirmed by biopsy of a gland from the neck or axilla If deep X-ray therapy is used there is usually a rapid temporary decrease in the mediastinal shadow, estimated radiologically



(a) (b)

FIG 20 2

(a) Hodgkin's disease (lymphadenoma)

Gross involvement of mediastinal glands

(b) Sixteen months later after deep X-ray therapy

(Dr J Bromley's patient)

The differentiation of the condition from retro-sternal goitre is of the greatest importance, as that condition is curable by surgery and many patients are still referred to radiotherapy units for treatment while some of the patients die without reference to a surgeon (see retro-sternal goitre, p 473)

The diagnosis of bronchiogenic or gastrogenous cysts depends largely on radiological appearances The neurofibroma perhaps has the most characteristic appearance, usually presenting a clear-cut ovoid opacity with smooth edges in the posterior mediastinum

Boeck's sarcoidosis, by its involvement of the parahilar glands, may produce considerable enlargement of the mediastinum, but usually there are typical associated lesions in the lungs with glands involved elsewhere and with changes in the eyes or spleen, or characteristic bony foci in the radiograph of the bones of the hands and feet

Tumours of lymphatic origin

Many thoracic surgeons with a wide experience and with access to autopsy examinations of mediastinal tumours have seen few proved examples of ' lymphosarcoma In the literature much confusion has arisen over the use of such terms as lymphoma This often includes such conditions as Hodgkin s disease reticulosarcoma and thymomata arising from the lymphatic elements of the gland

Mediastinal swelling due to tumours of lymphatic origin whatever their type are usually radio-sensitive in the first instance and this may be of considerable diagnostic assistance though it must not be forgotten that large metastatic masses secondary to anaplastic bronchial carcinoma also diminish after such treatment Most patients with lymphadenoma are not seen by surgeons and their true incidence is not apparent Heuer and Andrus (1940) in diagnosing 145 mediastinal tumours found that 29 were due to Hodgkin s disease

Tumours and enlargements of the thymus glands

Myasthenia gravis Surgical interest in the thymus gland is largely due to the work of Blalock (1939 and 1941) and Geoffrey Keynes (1946) Our inadequate knowledge of thymic physiology does not allow an accurate understanding of thymic deficiency or hyperfunction and this is accompanied by confusion concerning the pathology of thymic tumours The malignant thymoma may be called a lymphosarcoma by one pathologist and a carcinoma

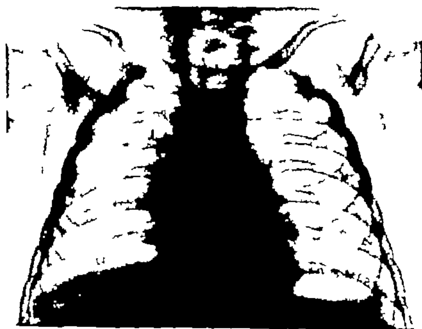


Fig *0-3 — A triangular shadow to right border of the heart in an infant A typical thymic shadow

by another it may or may not be associated with myasthenia gravis the one of epithelial origin is rarely radio-sensitive though hyperplasia of the gland in infancy and the lympho cytic group of tumours can be rapidly reduced by deep X ray therapy

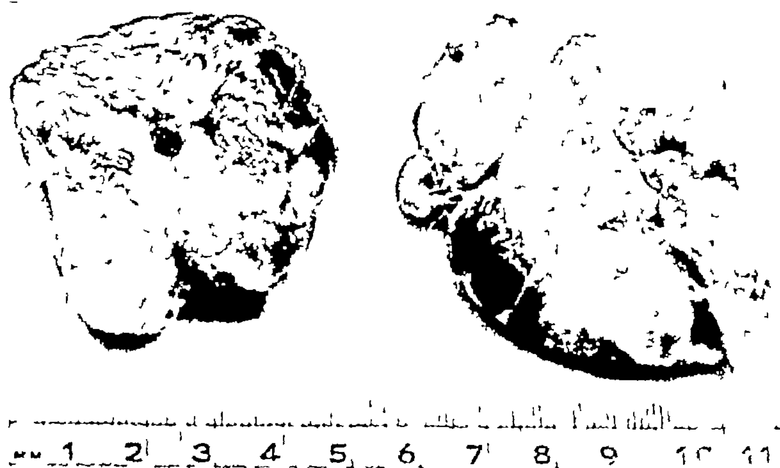
Aberrant thymic tissue The thyro-thymic lymphatic connections are well known (Williamson and Pearse 1930) and enlarged thymic tissue is sometimes found in close contact with the lower poles of the thyroid gland thymic tissue may be found as a con glomerate mass well away from the mediastinum An example of this in a girl of 23 with no symptoms is given on page 280 a solid tumour dissected from the region of the

hilum in the depths of the great fissure proved on histological examination to consist of normal thymic tissue, the patient was in perfect health four years later

Thompson (1951, personal communication) has told me that in two "spring-water" cysts (see p 481) which he removed, thymic tissue was present in the cyst walls and the conjecture that some of these serous cysts may be of thymic origin is of interest



(*a*)



(*b*)

Fig 20 4

(*a*) Radiograph of the chest in a child of 18 months showing broadening of the mediastinum Although the mass projects to the right side the trachea is also displaced to the right and at operation for the relief of the severe compression it was the left lobe of the gland that was the main cause of the pressure (see text)

(*b*) Hypertrophied thymus removed for the relief of severe mediastinal compression The right and the left lobes are pictured

Thymic hypertrophy in infancy It is unwise to diagnose this condition except in the presence of firm radiological evidence Thymic asthma and status lymphaticus are no longer accepted as clinical conditions and earlier attempts to remove these glands for the relief of symptoms are quite discredited (Keynes, 1946)

Broad mediastinal shadows seen in many infants are often due to enlargement of the superior mediastinal veins and vary greatly at different stages of breathing being accentuated by the act of crying A true enlargement of the thymus (usually symptomless) can however be demonstrated radiologically characteristically the lower border of the gland is separated from the mass of the heart with which it forms a typical angle or notch or overlies it like a jib sail (F H Kemp 1948) The onset and continuance of stridor and of severe dyspnoea in an infant with a radiological shadow of superior mediastinal enlargement does however justify the rare diagnosis of thymic obstruction deep X ray therapy will relieve the condition unless it is a malignant thymoma Most exceptionally an excision of the obstructing thymus is justifiable

A male infant aged 18 months was brought to the Children s Hospital because of frequent fits When he lay down severe cyanosis developed to be followed by a period of unconsciousness clearly the result of cerebral anoxia stridor was frequent He was a well developed child with no obvious abnormality detected in the chest on physical examination A radiological examination (Dr Roy Astley) was carried out and the large mediastinal mass (Fig 20 4 (*a*)) detected While awaiting a bed for admission to the hospital for possible radiotherapy he became seriously ill and unconscious His mother brought him to the hospital at once On arrival he had regained consciousness but was cyanosed with difficult stertorous and stridulous breathing The right chest was opened two hours after his admission through the classical lateral thoracotomy performed across the bed of the resected fifth right rib A huge enlargement of the thymus gland was obvious The right lobe was easily removed but the trachea remained obstructed and displaced to the right side by the left lobe which was readily resected (Fig 20·4 (*b*)) Histological examination of the tissue showed simple thymic hypertrophy and hyperplasia (Dr Baar) The post-operative recovery was satisfactory

Myasthenia gravis thymic tumours

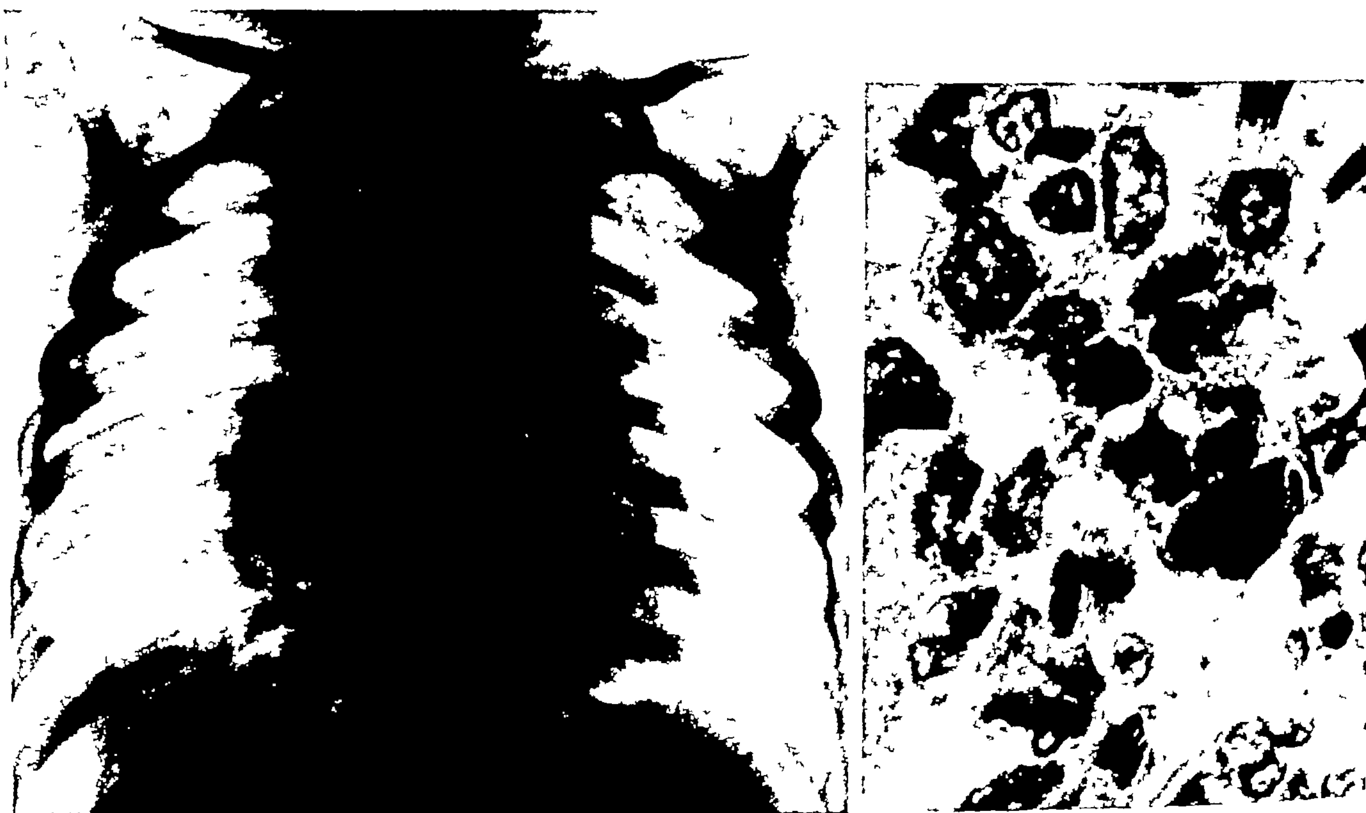
The odd fascinating and unexplained association between thymic tumours and myasthenia gravis must not obscure the fact that such tumours only arose in 11 6 per cent of 135 patients with the disease (Keynes 1949) and that no neuro muscular weakness may be present in others with thymomata The known association inaugurated the surgical treatment of myasthenia gravis initiated by Sauerbach in 1912 and thoroughly launched by Blalock (1937) in the United States of America and Keynes (1942) in this country Although Blalock was able to report promising results after removal of the thymus with true tumour formation Keynes with a large experience has described the progress in patients with thymic tumours after operative removal as unsatisfactory though the addition of pre-operative irradiation may have improved the prospects At the moment undoubtedly the best results after surgery in the treatment of myasthenia gravis are in those patients who have a simple thymus not necessarily enlarged but usually with an excess of germinal follicles

Thymoma It is probable that in the older literature many malignant thymic tumours described as primary epithelioma or lymphosarcoma were secondary to bronchial carcinoma and it is not a simple matter to estimate the proportion of malignant to innocent tumours In 1912 Poer reported autopsy results on 129 patients who had died from myasthenia gravis in 30 the thymus was enlarged there were 41 tumours of which 37 were regarded as benign and 4 as malignant in 1944 Blalock described two thymomata in 20 patients with myasthenia gravis on whom he had done thymectomy the remainder showing hyperplastic glands only

Malignant tumours of the thymus have been described by Ewing (1928) in three groups (1) Lymphosarcoma of the polyhedral and giant cell type (2) carcinoma developing in the epithelial cell nests of the glands and (3) a rare spindle-celled tumour of the type seen in myosarcoma The malignant tumours of this gland tend to compress tissues such as the

superior vena cava and the trachea and death is often the result of suffocation, but I have operated on a malignant tumour in a child that had widely invaded the pericardium and the lung. Since the diagnosis of malignant thymic tumours (apart from those with myasthenic symptoms) is rarely made until radiographs are called for in a patient with commencing suffocation the chances of surgical removal are not good and deep X-ray therapy is a temporary palliative.

Thymectomy for myasthenia gravis. The indications for removal of the thymus and the assessments of the results in a disease that has a peculiar natural history of notable remissions are far from simple. Since the relationship between the disease and the function of the normal or abnormal thymus is poorly understood the choice of treatment by surgery



(a) (b)

FIG. 20 5.—Malignant thymoma in an infant.

(a) The symptoms were dyspnoea and stridor. At thoracotomy a malignant tumour infiltrating the lung and pericardium was found. It was quite inoperable.

(b) The tumour consists of large cells in epithelial or syncytial arrangement with vesical and elongated nuclei. There are many binuclear or multinuclear cells and mitotic figures are frequent. (Dr. H. Baar.)

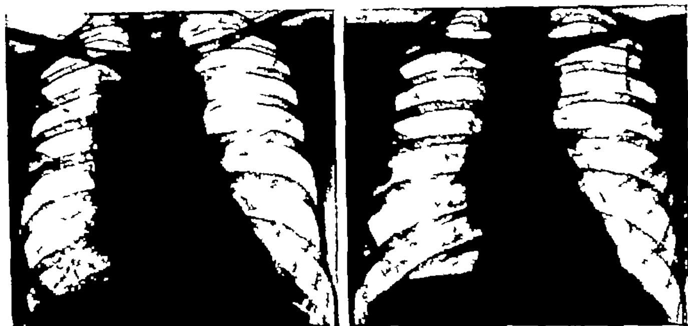
rather than by prostigmine or its related drugs will depend on the comparison of results obtained by a rather empirical operation and those of a medically treated series.

Keynes (1949), reporting his results in 155 thymectomies, was able to assess the effects on 120 patients (10 patients had died post-operatively, 18 had tumours and were considered separately and 7 for a variety of reasons were not yet assessed). Of the 120, 39 (32 5 per cent) were well, symptom-free and not taking prostigmine, 40 (33 3 per cent) were virtually well, but taking small doses of neostigmine, 31 (25 8 per cent) were unchanged in condition.

Kennedy and Moersch reported 87 patients with myathenia gravis who were seen between 1915 and 1932, an era when prostigmine or surgery was not available. Thirty-four of the patients died in periods varying from 6 months to 22 years. Harvey (1948) further studied this series and found that 27 of the patients had complete remissions which for

different periods lay between one month and 16 years In the same paper Harvey noted that prostigmine therapy greatly decreases the incidence of spontaneous remissions this observation is important because it enhances the good results of permanent remissions of the disease that follow thymectomy as almost invariably a myasthenic subjected to thymectomy has been and is being treated by prostigmine or neostigmine

The indications for surgery If thymectomy could produce a good result in all instances the present mortality rate (about 4 per cent or less in Keynes last 100 or so cases) would not be high enough to preclude operation but since perfect results are achieved in only about 40 per cent and there is no improvement at all in 8 3 per cent a selection of cases is still required since many myasthenics lead happy and useful lives if thoroughly treated by neostigmine in adequate doses (The need for and the safety of larger doses than those conventionally prescribed has been well reported by Viets 1950) The selection will largely



(a) (b)

Fig 20-6

(a) Radiograph of the chest of a woman of 34 years with a rapid onset of severe myasthenia gravis.
(b) Radiographic appearances five weeks after deep X ray therapy

In spite of this striking result there was no improvement in the symptoms these however regressed rapidly after thymectomy At operation the tumour was malignant and had partly invaded the right lung. The patient is well three years later

be in the hands of the physicians who will withhold operation from patients with minimal or moderate symptoms well controlled by *neostigmine* If large doses of this drug do not enable the patient to lead a reasonable life and especially if the drug is producing unpleasant side effects such as intestinal colic without improvement of the myasthenia operation should be advised The idea that those patients who have been given neostigmine for a long period will not benefit from operation is doubtful and the best result in my own short series was in a patient who had received prostigmine or neostigmine for nearly ten years

There is a tendency to withhold operation in older patients over 40 years (Viets) but Keynes believes that the age of the disease is more likely to militate against a good result than the age of the patient Probably the best surgical results are in the age group 20–30 with a short history of the disease

Tumours of the gland as visualized by radiology are an indication for operation but Keynes (1949) advises a course of deep X ray therapy before operation and believes that

the results after this combination are better than when operation alone is employed. Considerable shrinkage of the tumour may follow deep X-ray therapy but the symptoms of myasthenia may not be relieved. In two of our patients a rapid decrease in the size of thymic tumours was followed by an aggravation of the symptoms of myasthenia.

The size of the gland removed and its relation to the results. In his last review Keynes is careful to point out that the glands removed are frequently no bigger than those found at the same age in people without myasthenia and that size bears no relation to the severity, course or prognosis of the disease. The outstanding difference in the myasthenic thymus is the consistency with which conspicuous lymphoid germinal centres appear in contrast to their rarity in the glands of other subjects and Viets (1950) reached the same findings.

The operation of thymectomy. *The approach.* Although the thymus can be removed readily by a transpleural approach, excision through an upper median sternotomy is preferable because it enables a complete thymectomy under direct vision to be carried out. through the median incision the chief anxiety, the securing and ligation of the thymic veins draining into the innominate vein, is overcome because the exposure is direct and the great vein is easily identified and cleared. The objection to a transpleural approach on the grounds that it increases the post-operative respiratory complications is doubtful and on three occasions I have opened the pleura accidentally during a trans-sternal thymectomy without any post-operative sequels of an unpleasant nature. such an opening will have no ill effects if all the air is withdrawn by an artificial pneumothorax apparatus after the closure of the wound and the full re-expansion of the lung proved by a radiograph taken before the patient leaves the theatre. The preference for the median approach is based on the good surgical access it provides. there is a place for the more formal thoracotomy transpleural approach when large thymomata have been disclosed on a pre-operative radiograph (Fig. 20.4).

Pre-operative measures and anaesthesia. The dose of neostigmine known to afford benefit is maintained right up to the time for operation. no purgative or enema is given as these exhaust an already weakened patient. Preliminary postural drainage exercises and education in the use of an oxygen tent are taught for some days before operation by the nursing and physiotherapy staff and the need for post-operative efforts at expectoration indicated, together with an explanation that assistance may be given post-operatively by the use of intratracheal or bronchoscopic aspiration. In our own series we have not experienced difficulty about post-operative collections of mucus in the bronchial passages and I think the routine " cough " discipline in a thoracic ward largely dissipates this fear. It is possible that over-dosage with neostigmine during the operation may be a cause of pulmonary oedema (Viets, 1950). The dosage in the theatre may be based on the following formula. 1.5 mg. of neostigmine bromide is the equivalent in effect of 0.5 mg. administered intravenously, and the appropriate dose can therefore be estimated. Atropine sulphate gr. $\frac{1}{100}$ is also given pre-operatively.

Anaesthesia is induced by pentothal, a very much smaller dose being required than in the usual type of thoracic case and is maintained by a gas–ether–oxygen mixture. Curare is contra-indicated in view of the suggested biochemical basis of the disease in which a curare-like substance is thought to exist at the neuro-muscular junction. The essential anaesthetic requirements are a perfect airway and an adequate oxygen supply.

The operation. The patient is placed in the usual thyroidectomy position with a small sand-bag or flat pillow under the shoulder, the neck is extended and the head lowered as far as possible within the anaesthetist's requirement for providing a good airway. Local anaesthesia (0.5 per cent procaine in saline) is injected subcutaneously above and along the front of the sternum. A transverse incision three inches in length is made half an inch above

the sternum and a flap raised containing skin and platysma sufficient to expose clearly the sternal heads of the sterno mastoid muscle and the space of Burns any veins joining the jugulars across this space are isolated ligated and divided A meticulous exposure of the curved upper border of the sternum is essential and by the combination of finger and pledglet dissection the posterior surface of the bone is cleared portions of the infra hyoid muscles are divided

From the centre of this transverse incision the skin over the middle of the sternum is incised down to periosteum as far as the fourth costal cartilage bleeding is checked by the application of artery forceps to the divided edge of the pectoralis major muscle and these are placed close together and rolled outwards as in the manner employed in checking bleeding from the scalp by seizing the galea aponeurotica Large vessels are sealed off by applying the diathermy point to the artery forceps that have picked them up The sternum should be widely exposed the wound edges being firmly retracted after gauze pads have been placed under the retractors The fourth right costal cartilage is then exposed and its perichondrium elevated after the anterior aspect of this sheath has been incised it strips badly but every effort must be made to clear its posterior surface thoroughly so that a small Doyen s raspatory can be passed below it to maintain an intact pleura A small portion of the cartilage may be excised flush with its sternal junction the fourth left cartilage is dealt with in the same way Frequently however the lateral border of the sternum can be exposed sufficiently to allow of its transverse division without any resection of the costal cartilage

Working as close to the sternum as possible a curved Price Thomas elevator is used to clear it of the loose areolar tissue that lies between it the reflections of the pleura and the pericardium slowly a way is cleared until a curved metal instrument of the Adson elevator type can be passed from the bed of the resected cartilage to the corresponding site on the other side the sternum is then divided at this level by the Lebsch s chisel Schumacker or Exner bone cutters A thin bladed osteotome is then introduced beneath the upper end of the divided sternum on each side and when the bone has been elevated the loose areolar tissue beneath which is closely applied to the thin pleural membranes on each side is gently brushed aside by mops on long curved artery forceps It is easy to tear the pleura at this stage unless the greatest care is exercised If this clearing is carefully but adequately done a complete freeing of the posterior surface of the sternum is readily achieved and is combined with a similar attack on the back of the bone at the upper end The sternum is then free from all mediastinal tissues and can be readily divided by the Schumacker Exner s bone cutting forceps or by a mallet and osteotome Bleeding from the cut oozing surface of the vascular sternum is checked by the application of Horsley s bone wax.

Once the sternum has been freely divided a pair of double blunt hooks are used one on each side to lift and separate the divided segments through the gap so created a single Tuffier retractor is inserted and when this is screwed open a wide exposure of the superior mediastinum is obtained This space is covered by a relatively strong layer of fibro fatty tissue which forms a real sheath to the thymus gland at first it may be mistaken for the gland itself It is freely opened after being held up between two pairs of artery forceps and entered by the use of fine *curved scissors* The opened fascia when brushed aside displaces the pleura laterally with it but the pleural membrane on each side comes very close to the mid line and should be pushed aside by moist pledglet dissection before the actual opening is made into the fibro fatty envelope

When this sheath has been widely opened the yellowish pink thymus gland is seen and its extent varies greatly the two lower poles always reach well down on to the pericardium



Fig 20 7—Exner's bone cutting forceps, hammer and broad-bladed osteotome, useful instruments for sternal division

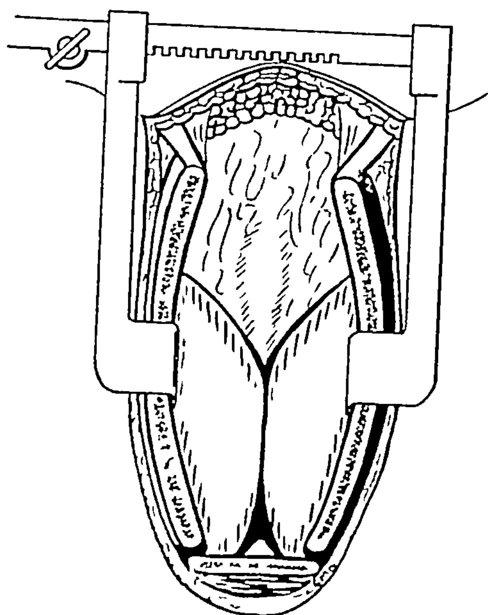


Fig 20 8—Upper medial sternotomy The areolar tissue above the two pleural sacs covers the thymus



Fig 20 9—A thymus gland removed from a patient with myasthenia gravis (natural size)

and they should be elevated after being grasped in light mosquito-artery forceps and peeled off the sac by pledglet dissection No large vessels are met until the upper poles of the glands are being secured The gland is slowly lifted upwards until the innominate vein is seen on its deep surface As the dissection proceeds at this stage the greatest care must be taken to identify the thymic veins there are always two branches occasionally more and they enter as separate trunks of some size into the innominate vein They are seized divided and ligated and then the upper poles usually in the shape of two thin horns are followed up to the neck where they appear to run into the lower poles of the thyroid small arteries are present at this level and require ligation The thymus gland strips easily from its mediastinal bed and apart from possible injury to the thymic vein and the



FIG 20-10 —A large thymus removed from a child of 12 years with severe myasthenia gravis (natural size)

pleura there are no hazards When the bed is completely dry the wound is closed the divided sternum is readily approximated if the shoulders on each side are held slightly upwards The divided sternum is then lashed together with two silver wire sutures passed through drill holes made on each side with a brace and bit interrupted thread sutures are passed through the thicker fibrous tissue that spreads out into the pectoralis major muscle and are sufficient to secure and maintain approximation

The neck wound is closed in the usual way after the platysma has been sutured by 0000 catgut Michel s clips may be used in the neck skin but the sternal portion is better closed by interrupted black silk sutures A small drain is left in the neck wound for 24 hours

Post-operative treatment The bronchial tree is aspirated dry at the close of the operation and further neostigmine is given by subcutaneous injection the patient is returned to an oxygen tent for the first 24-48 hours The main post-operative care is to ensure a clear tracheo bronchial tree and the usual measures to achieve this are taken

Thoracic goitre

Intrathoracic goitre is not always as simple from the diagnostic and excisional point of view as is frequently believed Many goitres have substernal prolongations which provide

no difficulty during thyroidectomy as they are dislocated upwards with ease if the plane of dissection is in the true peri-thyroid space Even those of large size that reach far down into the thorax to overlie the pericardium are readily delivered, but all thoracic goitres do not follow the common pattern, and every thoracic clinic receives patients who have been referred as malignant mediastinal tumours and may have been subjected to deep X-ray irradiation All intrathoracic goitres do not have a connection with the gland in the neck, though most of them do nor do all intrathoracic goitres enter the chest in front of the innominate vein, trachea and oesophagus, a few proceeding down behind the clavicle to enter the thorax and assume a position deep to these structures.

Finally in analysing the unusual from the common, thoracic goitres do not necessarily draw their arterial blood supply from the neck through the inferior thyroid artery, exceptionally they have an arterial supply from the aorta or from one or other subclavian artery.

The diagnostic and surgical approach should not be oversimplified though most of these goitres can be removed safely through a collar incision, occasional ones require a trans-sternal or even a transpleural approach The surgeon, quite exceptionally, must be prepared to split the sternum do a thoracotomy posteriorly or enlarge the neck incision into a sternum-splitting operation

Diagnosis The onset of compression symptoms affecting the trachea and rarely the oesophagus in a known goitrous patient, makes for an easy diagnosis which radiology of the thoracic involvement will confirm the radiological examination will disclose the site of the mass and the extent and type of tracheal distortion Rarely the intrathoracic goitrous prolongation will lie behind the trachea and the oesophagus this I have seen four times and two of these patients have been recorded (Tomkinson, 1951) Keynes (1950) has reported two in the posterior mediastinum and Sweet (1949) describes six in a lucid and full account of thoracic goitre

The difficult diagnosis is concerned with those patients who at their history taking fail to disclose that at a younger age they had a goitre that disappeared gradually. such a slow disappearance may have been completely forgotten until they arrive at hospital because of dyspnoea, stridor and the other symptoms of upper thoracic compression This may be instanced by two short histories

Mrs D, aged 50, was referred for opinion because of increasing dyspnoea and stridor, associated with gross distension of the veins of the head, neck, and arms for six months the symptoms had progressed relentlessly and she could only walk 20 yards The voice had altered in pitch and tone and there was some hoarseness A diagnosis of malignant mediastinal tumour had been made and she was sent for deep X-ray therapy The radiograph (Fig 20 11) shows a mass to the right of the mediastinum without the clear lower border usually, but not invariably, associated with a retro-sternal goitre it lay nearly in front of the trachea which was displaced to the left.

On close questioning she disclosed that from the age of 15 to 25 she had had a very full neck of which her family used to make fun by the time she was 30 the neck was entirely normal, and the disappearance was attributed to the use of iodine ointment Through a collar incision an intrathoracic goitre was removed easily

Mrs T, aged 39 suffered from repeated coughs and pain in the right chest · a pleural effusion had developed six months before after a pyrexial illness No actual evidence of tuberculosis was obtained but this was considered to be the cause of the effusion Because of repeated attacks of respiratory obstruction and the radiological evidence of a tumour arising on the right side of the mediastinum she was referred for surgical treatment (Dr Brian Taylor) Radiological screening of this patient showed that a portion of this ovoid tumour lay behind the trachea and the oesophagus Because of the central mass of calcification, which was erroneously regarded as being a plaque of bone the pre-operative provisional diagnosis was "dermoid cyst" (Fig 20 12)

The right chest was opened by a posterolateral thoracotomy through the bed of the fifth rib.

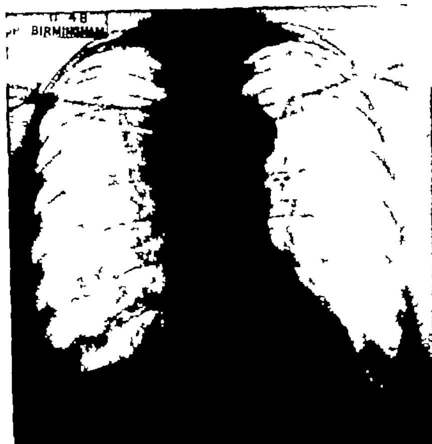


FIG 20-11 —Not a typical picture of retro-sternal goitre because of the indefinite outline of the lower edge

A very clear history of goitre that had disappeared was of considerable help in the diagnosis (see text).



FIG 20-12.—Radiograph of a woman of 30 years showing a mass in the region of the right side of the superior mediastinum with an area of calcification in it

The lateral radiograph showed it to lie well behind the line of the trachea and oesophagus the [illegible] diagnosed was not thoracic goitre (see text)

As soon as the tumour was exposed the diagnosis was obviously that of intrathoracic goitre, as the tissue was typically thyroid in appearance the blood vessels came from above and application of ligatures to them from this thoracic approach was difficult The tumour, in spite of its posterior position, would have been more easily removed through a cervical incision

When told on the day after operation, that the "tumour" was a goitre, the patient surprised us all by saying that she had wondered where the goitre which she was conscious of in adolescence had gone to ! Such a history obtained pre-operatively in combination with the calcification which is so often seen in long-standing thyroid adenoma would have enabled a correct diagnosis to be made

Ectopic intrathoracic goitre

Occasionally a thyroid may develop in the mediastinum without any connection with the cervical gland and with an independent blood supply (aberrant or ectopic mediastinal goitre) Such tumours may be diagnosed as aneurysms or true mediastinal neoplasms

Mrs E, aged 49, had suffered from attacks of dyspnoea of some severity for 8 years At another hospital on two occasions bilateral cervical thyroidectomy had been done for a large colloid goitre, the second operation being for a recurrence of the mass two years before her admission to hospital When the radiograph (Fig 20 13 (*a*)) was taken she had considerable stridor and could only sleep in a propped-up position There was a considerable recurrence of the goitre in the neck on the left side

At operation, the neck was exposed and the large left lobe of the thyroid completely removed There was no connection between the gland and the mediastinal mass which could not be felt through a retro-sternal dissection. the sternum was therefore split and a large mass of thyroid removed from its position overlying the pericardium the blood supply to this ectopic thyroid tumour in the chest was from two branches which arose directly from the aorta

Differential diagnosis of thoracic goitre Apart from lymphadenoma and secondary involvement of the space by extensions from malignant bronchial tumours, intrathoracic goitre is the commonest cause of a space-occupying tumour of the superior mediastinum The symptoms it causes unless there is the complicating factor of thyrotoxicosis, are those of superior mediastinal compression with dyspnoea, stridor, engorgement of the neck veins and persistent cough. as the most striking Hoarseness is sometimes a symptom and may be attributed wrongly to a malignant invasion of the recurrent laryngeal nerve Dysphagia is not so frequent as dyspnoea but does arise occasionally

Mistaken diagnoses include aneurysm of the aorta, or innominate artery, Hodgkin's disease. neurofibroma (which is almost universally sited posteriorly), dermoid cysts, thymic tumours, a dilated oesophagus in patients with severe cardiospasm and mediastinal abscess (Fig 20 14)

The radiological features are usually typical

The tumour may be seen on both sides of the mediastinum or may deviate to one side alone The outlines are usually clear though often irregular if there are false adenomata present The trachea is typically displaced backwards and to one side, and a continuation of the shadow above the clavicle is usually seen Calcification is an occasional finding If there is radiological difficulty in establishing the diagnosis radio-isotopes are of value after these have been absorbed the Geiger counter may be useful in showing that the mass contains thyroid tissue (Touroff. 1950).

Surgical treatment of thoracic goitre. If thyrotoxicosis is present the patient should be treated by bed rest. iodine and sedatives as a pre-operative measure thiouracil may be dangerous as the increase in the size of the gland in its confined quarters might precipitate or aggravate tracheal obstruction As already stated the goitre can be delivered

quite easily from a neck approach if the peri thyroid space is carefully exposed and entered If the goitre cannot be delivered because of its size (which is due to the adenomatous enlargement often aggravated by the pathological complication of necrosis cyst formation

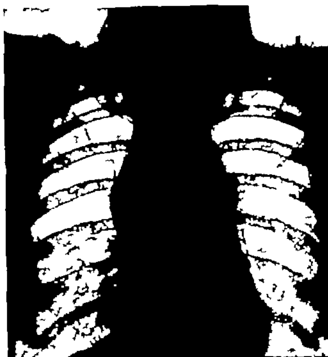


FIG 20-13 (a) —Radiograph of the chest showing a large mass in the mediastinum (see text)

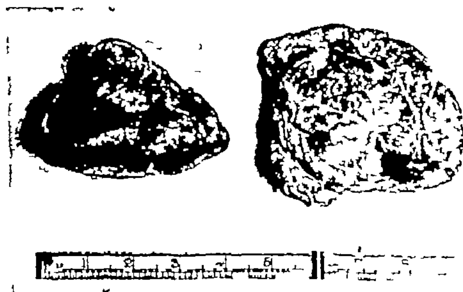


FIG 20-13 (b) —Photograph of thyroid tissue removed.
The mass on the left was the hemi-lobectomy specimen removed through a neck incision, that on the right being the mediastinal goitre which had no connection with the cervical goitre and received an independent blood supply from the aorta.

haemorrhage and calcification) the centre of the goitre may be removed to decrease the bulk of the tumour which can then be delivered easily In exceptional instances the sternum may require division and instruments should be at hand for this I have had to split the

ternum twice in fifty operations for thoracic goitre The retro-oesophageal goitre can be elivered from the neck without the need for thoracotomy in most instances, though division f the sternum is sometimes essential for safe resection (Keynes, 1950)



Fig 20 14

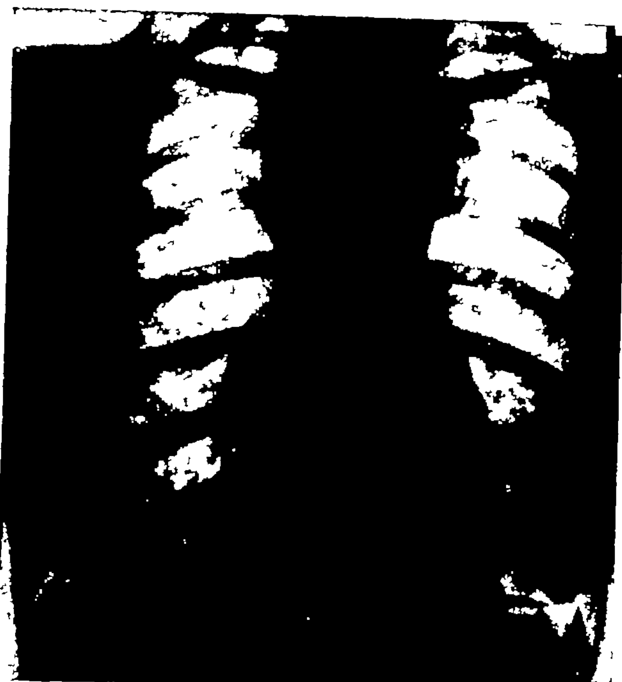


Fig 20 15

ig 20 14—A tuberculous mediastinal abscess developing in a patient with a left artificial pneumothorax This abscess pointed above the right clavicle The left pneumothorax was abandoned and the abscess, which became secondarily infected, was drained by a right costo-transversectomy (Yardley Green Hospital)

Fig 20 15—A typical bilateral intrathoracic goitre

Dermoid cyst or teratoma

The commonest site for these "tumours" apart from the ovary is in the anterior ediastinum usually they contain all three germinal elements The condition is not mmon Harrington with a vast experience of mediastinal surgery had 16 personal cases to 1937 Rusby (1944) in a complete review analysed 251 examples I have only erated upon five and have seen three others Usually they have a simple pedicle conning vessels from the parietal pericardium and if uninfected, without bronchial connection d have not undergone malignant change, are well encapsulated and easily removed They not always arise in the anterior mediastinum and I have removed one from between the iphragm and the right lower lobe of the lung, and one from the left posterior mediastinal ace

Pathology and natural history The solid teratomatous tumour may show early signs malignant transformation as in the testis or ovary, the large cysts with smooth walls and baceous contents probably do not develop malignant tendencies The cyst of this type s a lining of skin supplied with the usual secreting glands and there may be teeth or bony ments present They cause their effects by pressure The solid dermoid tumour is obably a different condition from the outset, the term "cyst" is not truly applicable it is essentially a solid complex mass composed of derivatives of all three germinal layers en containing cartilage bone, gastro-intestinal and respiratory elements and nervous sue These tumours are rare





FIG 20·16 FIG 20·17

FIG 20·16.—Large dermoid cyst in the typical anterior position.

Severe compression symptoms causing frequent fainting attacks brought the patient for examination. At operation a large cyst full of sebaceous material and hair was removed. There was complete relief of symptoms and patient is well three years later.

FIG 20·17.—Large dermoid cyst of the anterior mediastinum with a tooth seen.

The tumour is so large that the chest wall is bulging.





(a) (b)

FIG 20·18

(a) Solid teratoma of the mediastinum.

There was severe dyspnoea. The tumour was occupying a large amount of space in both sides of the chest. It was removed with complete relief of symptoms (Dr O. Brenner's case).

(b) The tumour after removal through a wide left-sided thoracotomy.

The tumour was so large and bulky (… cm) that considerable difficulty was experienced in delivering it. Histologically there was no malignant change and the patient is well four years after operation.

Symptoms and diagnosis Symptoms will only develop as a result of pressure, malignant transformation or infection symptomless dermoids may be detected in routine or mass radiography reviews, the large ones, however, cause pressure effects such as dyspnoea, cough, pain and palpitations The chest wall may bulge as the result of very large cysts (Fig 20 17), and the heart be grossly displaced Dullness on percussion may be detected on one or both sides of the sternum The cyst may rupture into a bronchus causing expectoration of sebaceous greasy material, followed later by purulent sputum the result of secondary infection developing from the eroded bronchus

Differential diagnosis They require differentiation from thoracic aneurysm and para-mediastinal empyema The absence of tracheal tug and of the other signs and symptoms of aneurysm (especially the cardiac ones) will help in the clinical differentiation A more exact analysis is possible by the use of angiocardiography Para-mediastinal empyema is usually associated with a quite different antecedent history in which cough and pyrexia may have been prominent features The diagnostic exclusion of other conditions such as bronchiogenic cysts, lipoma, and other rare encapsulated tumours may be impossible, but these can be removed through the incision that would be selected for operation upon a mediastinal dermoid The differentiation from a retro-sternal goitre is, however, important, as the latter requires usually a cervical approach for its excision The radiological appearances of retro-sternal goitre are usually quite different

Large cysts in the inferior mediastinum may so obscure the heart shadow that a diagnosis of pericardial effusion may be made this error is not made if the apex beat is palpable in a displaced position which is usual, but the tumour may be so large that the apex cannot be accurately located (Fig 20 18)

Radiological appearances Usually the shadow of a typical cyst has a smooth clear circular outline which becomes broadened out into a flat base at the origin of the mass from the mediastinum this flat base is seen on the lateral view (Fig 20 19) The shadow can be separated from the cardiac silhouette on the screen the chief difficulty is experienced when the cyst has caused compression of the lung or has even occluded the bronchus, for then the outline of the cyst is not clear, merging with the shadow cast by the consolidated or atelectatic lung tissue Transmitted pulsation of the heart beat to the tumour is common on screening and this may lead to an erroneous diagnosis of "aneurysm"



Fig 20 19—Lateral radiograph of dermoid cyst showing the typical flat base behind the sternum

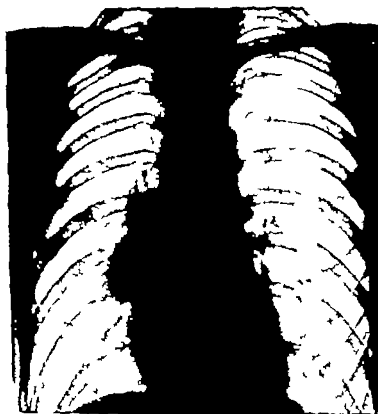
Treatment Except in the face of exceptional contra-indications removal should be advised to avoid the dangers of thoracic compression, malignant degeneration, cardiac disturbance and secondary infection The approach is by a large transpleural thoracotomy, the side containing the largest projection of the tumour being selected The mediastinal pleura over the tumour is opened widely and the cyst enucleated from its false sac Usually there is a well-developed layer of areolar tissue and as this is stripped the

pedicle which may be single or multiple is defined the vessels in it are not often large The chest is usually closed with drainage for 24 to 48 hours

If the cyst has been drained previously the operative removal may present formidable difficulties and malignant change with spread to the mediastinum may make this impossible

Pleuro-pericardial cysts (spring water cysts)

Thin walled serous cysts lined by endothelium are occasionally found adjacent to the pericardium or in the cardio-phrenic angle either anteriorly or posteriorly and at operation appear to rise from the parietal pericardium less commonly they develop in the superior mediastinum or are sited just above the diaphragm A similar type of cyst is found attached to the parietal pleura or the diaphragm (d Abreu 1937) Their chief importance is from the



(a)



(b)

Fig 20·40

(a) Radiograph of pleuro-pericardial cyst

(b) Excised pleuro pericardial (spring water) cyst

diagnostic aspect Rarely do they cause pain or pressure symptoms and an increasingly large number are being diagnosed in symptomless patients who have undergone miniature mass radiography examinations Because of the increasing use of exploratory thoracotomy for most patients with tumours as measures designed to excise all possibly malignant lesions and because so many of the intrathoracic swellings ultimately cause pressure symptoms a few of these cysts are removed annually in most centres As mentioned elsewhere Barrett has indicated that because of their laxity considerable deformation of their shape is usual after the induction of an artificial pneumothorax and this physical sign might well support a conservative abstention from surgery The cysts have a simple endothelial lining to

which occasionally is attached thymic tissue (Thompson) It is only possible to suggest that they are congenital in origin it is not surprising that the complicated embryological process of pleural, pericardial and diaphragmatic development should be associated with "inclusion" cyst formations They may be associated with pericardial defects, why they sometimes cause pain is difficult to explain

The diagnosis from the radiological features is by a process of exclusion or as the result of an exploratory thoracotomy for a thoracic tumour. Their removal is simple and they readily strip from the pericardium

POSTERIOR MEDIASTINAL TUMOURS

Carcinoma

Involvement of the posterior mediastinum by gross lymphatic enlargements secondary to bronchial carcinoma is common, this enlargement is often detectable radiologically with or without a barium swallow Occasionally such involvements are out of all proportion to the size of the primary tumour in the lung and an exploratory thoracotomy may be done because the mass has been regarded as an encapsulated innocent tumour.

Neurogenic tumours

The clinical diagnosis and excision of these tumours is simpler to describe than their complicated pathology, they represent an important group of tumours seen in children and adults Many more have been excised than have reached the literature and their detection has been increased since the use of mass radiography They represent the most important group of tumours met with in the posterior mediastinum Arising from nerve elements they show features of fibrous and nervous tissue which may arise from the central or sympathetic nervous systems tumours of sympathetic origin are commonest in children and may be ganglio-neuromata or sympathetico-blastomata In the usual tumour as seen in adults fibrous tissue elements predominate, hence the common name "neurofibroma", or the less commonly used term "perineural fibroblastoma".

When malignant change takes place (in 41 per cent of cases according to Blades, a figure regarded by many as surprisingly high) the tumour usually has the characteristics of a sarcoma In my own experience of 20 neurofibromata two have been malignant. Typically these tumours enlarge to ovoid shapes which grow out into the hemithorax occasionally they burrow into the vertebral foramen and may produce pressure on the spinal cord Symptoms when present are from pressure on adjacent structures such as the nerve of origin (Fig 20 24), the spinal cord (Fig 20 28), or the bronchus (Fig 20 27) Pressure upon the overlying ribs or involved thoracic vertebrae may produce a combination of distortion, decalcification and sclerosis Although essentially developing in the posterior mediastinum neurofibroma may quite exceptionally be elsewhere, I have seen one in the anterior part of the chest overlying the pericardium (d'Abreu, 1947) and three arising from intercostal nerves well away from the posterior part of the chest

Large masses may develop in the chest of patients with generalized neurofibromatosis (Von Recklinghausen's disease) These tumours may be in the posterior mediastinum involving at times many intercostal nerves, or they may enlarge anywhere in the line of the intercostal nerves their tendency to sarcomatous change is well known

The pathology of these tumours is difficult and varying histological reports state that some are true neuromata with a fibrillary structure resembling that of peripheral nerves:



Fig 20·21.—Parietal tumour overlying the 8th and 9th right ribs in the axillary line

Histologically the removed tumour was typically that of neurofibroma.

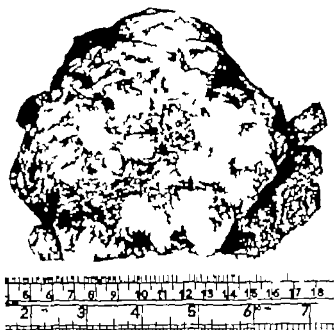
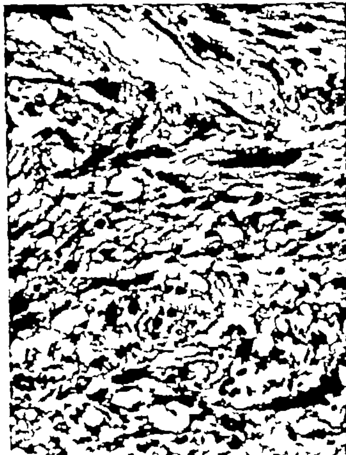


Fig 20·22.—Sarcomatous change in a neurofibroma from a patient with generalized von Recklinghausen's disease



(a)



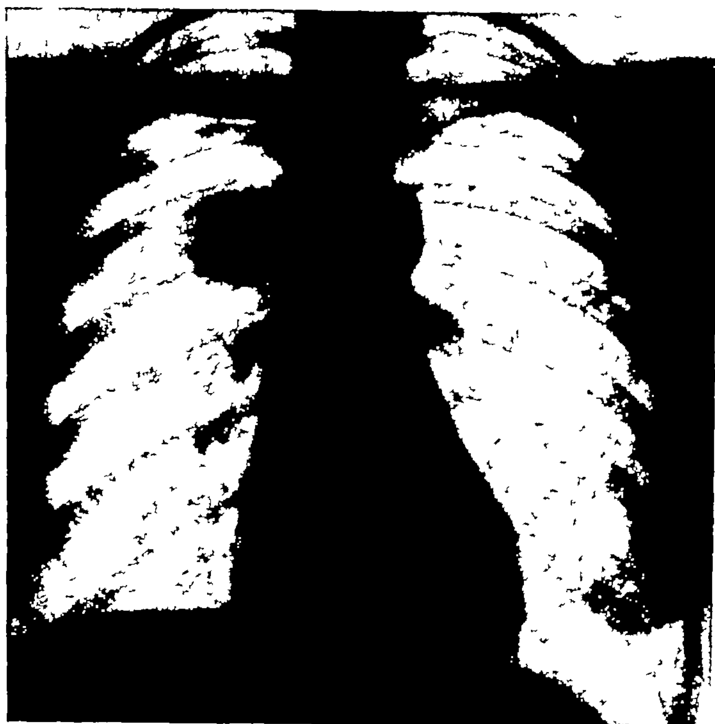
(b)

Fig 20·23.—An encapsulated benign tumour showing areas of vascularity and haemorrhage

The elements of the tumour are fibrous tissue and nerve fibres. The characteristic arrangement of cells in a neurinoma is seen in some parts. (a) × 100 (b) × 400. (Prof J W Orr.) Photomicrograph by Dr J G Jackson.

others undoubtedly are tumours primarily of the nerve sheath (Schwannoma, perineural fibroblastoma), and a compound variety is described in which neural and fibrous elements are intermingled

Generally the tumours remain encapsulated unless sarcoma develops and all are liable to cystic and myxomatous changes, which by no means indicate a malignant transformation in all instances Usually the pedicle of the tumour contains a nerve and a sheath of blood vessels





(*a*) (*b*)

FIG 20 24

(*a*) Radiograph of the chest of a woman of 40 years

The X ray examination was carried out because of pain in the line of the 6th intercostal nerve

(*b*) Neurofibroma removed at operation

The intercostal nerve is seen entering and leaving the tumour

Fig 20 25 is a radiograph of a child of six months who suddenly developed a complete paraplegia of the legs with sensory loss up to the nipple line the tumour in the left chest was submitted to exploratory thoracotomy An invasive tumour involving the left lung and the pericardium was seen to have its main pedicle of attachment posteriorly in the mediastinum Removal was impossible and the parents were given a hopeless prognosis No radiotherapy was employed A year later, the child was seen she was in perfect health and the paraplegia had completely disappeared A penetrating radiograph (Fig 20 25 (*b*)) indicates marked retrogression of the tumour and the upper lobe of the lung appears to be free from infiltration The ultimate prognosis is quite unknown

The more common tumour is undoubtedly a ganglio-neuroma, and this also has malignant tendencies, though less obvious than in the neuroblastoma type as the cells are well differentiated and the whole tumour encapsulated The sympathetico-blastoma type (neuroblastoma) behaves indeed very much like the Pepper-Hutchinson group of sympathetic neoplasms

Diagnosis and treatment of thoracic neurogenic tumours Some of these tumours are symptomless, being discovered on routine mass radiography whether free from symptoms

or not an exact diagnosis is required if possible as surgical opinion is unanimous in advising their excision because of the dangers of later compression or of malignant change The commonest symptom is pain which if present radiates along the line of the affected inter costal nerve the large tumours may cause dyspnoea and cardiac symptoms and the picture



(a) (b)

Fig 20-25

(a) Radiograph showing tumour of the left side of the superior mediastinum involving the lung—biopsy at thoracotomy malignant sympathetico-blastoma
The child had paraplegia (Dr H. Baar)
(b) Radiograph of the same child four years later
The child is well and the paraplegia has disappeared (see text).

of lung infection may be present if the tumour has caused atelectasis of part of the lung from pressure and inflammatory adherence of the capsule of the tumour to the lung may develop

The radiographs (Figs 20 26 20 27) are those of neurogenic thoracic tumours that have been removed by operation their histories are interesting The child (Fig 20 26) was referred to Dr A G Watkins as suffering from asthma for which she had been treated for years the apex beat of the heart was displaced to the right of the sternum and fainting attacks were common these and the asthma have disappeared completely since the removal of the tumour

Fig 20-27 is the radiograph of the chest of a young man of 20 who had three attacks of upper lobe pneumonia after the last attack the chest was X rayed with the appearances shown there is an obvious opacity of the right upper lobe of the lung beyond the edge of the tumour At thoracotomy an area of chronic suppurative pneumonia was resected together with the tumour he has remained at full work for over four years

Mrs S (Fig 20-28) had suffered from increasing dyspnoea regarded as asthma for three years She was admitted urgently to the Queen Elizabeth Hospital with severe stridor and considerable cyanosis an emergency thoracotomy was done and a large neurofibroma removed with immediate relief of symptoms

The radiological pictures usually show an ovoid tumour which on the lateral projection lies posteriorly but projected well forward

Before reaching a large size these tumours may be more rounded in shape (Fig 20 29)



FIG 20 26



FIG 20 27

FIG 20 26—Radiograph showing a large tumour in the left chest

A large ganglio neuroma was removed from this child of 8 years Histology revealed a typical ganglio neuroma The child is alive and well five years later (Dr A G Watkins' case)

FIG 20 27—Neurofibroma of the right chest associated with an inflammatory change in the right upper lobe of a man of 20 years



FIG. 20 28



FIG 20 29

FIG 20 28—Radiograph of a woman of 39 years

There was increasing dyspnoea for years, sudden stridor and extreme respiratory obstruction At emergency operation a neurofibroma was removed (see text)

FIG 20 29—A radiograph of a small tumour proved histologically to be a neurofibroma after excision

The symptoms were pain in the back and a diagnosis of tuberculous abscess had been made elsewhere

especially when sited at the apex of the chest The overlying ribs may be forced somewhat apart or show signs of distortion and sclerosis at the rib edges Rib changes even of the most marked degree *must not* be regarded as evidence of malignant change in the tumour

Treatment Surgical removal should be advised for the reasons given a wide trans pleural thoracotomy is done the pleura overlying the tumour widely incised and reflected The blood supply is from the posteriorly placed intercostal vessels and the tumour should be cautiously mobilized before these are clamped off as rough handling may cause them to bleed near their aortic origins If sarcomatous change has taken place the surrounding ribs may be removed together with the tumour but the operation may well have to be abandoned if the malignant extension is considerable The tumours are not radio-sensitive except in a few examples of *malignant* sympathetico blastoma in children.

Dumb-bell tumours

The spread of the tumour into the spinal cord through the intervertebral foramen is not common but paraplegia may be the first symptom

Mrs. L. L. was referred to Prof Brodie Hughes with paraplegia this had been slowly develop ing for a year she was sent in urgently because of the sudden onset of retention of urine



Fig 20-30 —The removed neurofibroma (8 cm.) The large intraspinal projection is t the right.

The radiograph of the chest showed the appearances typical of neurofibroma radiological studies of the *spinal column showed a great widening of the intervertebral foramen* at the ninth thoracic level. As an emergency procedure a thoracotomy was performed the neurofibroma had a wide necked prolongation into the spinal canal which it was impossible to deliver through the chest wound Prof Hughes did a laminectomy and the tumour was removed in one piece (Fig 20-30) The intraspinal prolongation was unusually long The patient made a complete recovery from the paraplegia

In the treatment of these dumb-bell tumours two-stage operations should be avoided

Bronchiogenic gastrogenous and enterogenous cysts

Since the lungs develop as out buddings from the primitive foregut duplications (Baar and d Abreu 1950) within the thorax are to be expected Misplaced areas of foregut tissue are usually situated in the posterior mediastinum and may develop into large cysts (Fig 20 31 (*a*)) at a later stage in embryological development sequestrated portions of bronchial elements likewise may grow in the posterior mediastinum and be quite separate from the



(a)



(b)

Fig 20 31

(a) Bronchiogenic cyst in a man of 28 years

Symptoms were those of pain in the upper chest and of chronic cough without sputum. A bronchiogenic cyst was removed through a postero-lateral thoracotomy

(b) Cartilage in relation to a bronchiogenic cyst (H E × 150)



Fig 20 32—Lower congenital accessory cyst with a secondary, developed opening into the left lower lobe

This is not a true bronchiogenic cyst though probably of the same origin, namely a duplication of the foregut. At lobectomy a large accessory artery was found coming through the diaphragm to supply the cyst (see Chapter 1, page 23)

lung itself to form what are usually described as bronchiogenic cysts These are not to be confused with the cysts found usually in the region of and attached to the lower lobes of the lung in association with an abnormal blood supply These mediastinal cysts contain fluid of varying appearance and in their walls may be typical bronchial mucous membrane (Fig 20 31 (*b*)) if the cysts are bronchiogenic and elements of the foregut if they are gastric or enteric They may cause symptoms by pressure effects upon the lung bronchi or oesophagus quite exceptionally the heart is disturbed by large varieties Peptic ulcer or erosions may develop in the gastric type and lead to haemorrhages Bronchiogenic cysts are usually high up in the mediastinum often with fibrous connections to the area of the tracheal bifurcation It is tempting to think that these displaced portions of bronchial tissue had their origin in the obliteration of the tracheo-oesophageal groove and represent minor deviations from the gross abnormality of tracheo-oesophageal fistulae Cysts lined by bronchial epithelium are sometimes found above the bifurcation to one or other side of the trachea such para tracheal cysts may derive from minor tracheal accessory lobes (see Fig 1 12)



Fig 20·33 —An enterogenous cyst causing displacement of the oesophagus.

The pre-operative diagnosis was neurofibroma or possibly an enteric or bronchiogenic cyst At operation the cyst had a pedicle that reached up to the bifurcation of the trachea

The surgical removal of these cysts may be difficult if they have developed fistulous communications with adjacent structures such as the trachea bronchus or oesophagus such communications must be deliberately divided and the openings into the viscera closed by careful interrupted sutures reinforced if possible by pedicled pleural flaps Once infection has developed the finding of surgical planes may be formidable

The radiological appearances are those of a tumour in the posterior mediastinum which may displace the trachea or the oesophagus

Miscellaneous mediastinal tumours

A wide range of tumours has been recorded usually in publications dealing with one or few cases lipoma fibroma zanthoma chondroma hydatid cysts and lymphangioma (Harley 1950) or cystic hygroma may be mentioned The lipomata may be of large size developing from the pleuro-pericardial fat and often late in producing symptoms their point of origin is almost invariably in the anterior mediastinum They may have intrathoracic and extrathoracic portions More and more of these tumours are being recorded following exploratory operations that have been advised after the detection by mass radiography of unexplained shadows They are by no means as simple as their name suggests Heuer and Andrus (1940) collected 28 examples of mediastinal lipoma of these 13 were untreated by surgery and died Their evil reputation is due to the fact that they may attain a huge size and occasion gross intrathoracic compression effects which produce cough and choking attacks pain dyspnoea and cyanosis They do not show lobulation on the radiograph but are usually less opaque at their periphery than at the centre

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PART VI

SOME MISCELLANEOUS CONDITIONS

CHAPTER 21

SURGICAL ASPECTS OF PULMONARY EMPHYSEMA

Emphysematous changes in the lung may be bilateral unilateral lobar or segmental a good deal of confusion exists in the whole group which ranges from large air cysts and diffuse cystic changes seen in infancy to the fully developed state of bullous formation in adults with generalized hypertrophic emphysema Cystic disease of the lung though occasionally congenital is frequently acquired It is often impossible even after full histological examination to decide whether these cysts are congenital or acquired but at all events they can be separated into two classes (a) those derived from the bronchial tree and (b) those of alveolar origin (Moersch and Clagett 1947) Surgery may be indicated for the mechanical embarrassments produced by emphysema and giant cysts and especially for the complication of chronic or recurrent spontaneous pneumothorax secondary to such conditions It is not possible to discuss in detail the physiopathology of these lesions which are described under a wide range of terms such as pneumatocele giant air cysts cystic or bullous emphysema and emphysematous blebs The term compensatory emphysema is applied to the enlargement of other lobes that follows permanent collapse or resection of other areas of the lungs and has been discussed elsewhere especially in the chapter on lung neoplasms with reference to the changes that follow total pneumonectomy

The assessment of patients with emphysema who have serious accompanying lesions such as bronchial neoplasm tuberculosis and bronchiectasis before major surgical operation is contemplated, is of obvious importance and has been discussed in Chapter 2 As the condition of true emphysema is irreversible pre-operative tests of lung function are not to be disregarded if major surgery is being considered. Patients with evidence of right ventricular heart stress are unlikely to survive excisional operations as they are already anoxic with a low vital capacity diminished arterial oxygen saturation and the other features that accompany the associated pulmonary hypertension

If patients with emphysema are subjected to surgery constant watch must be kept for the earliest signs of right sided heart failure the onset of cyanosis a raised pulse rate elevation of the jugular venous pressure the presence of capillary pulsation and faintness of the heart sounds are important clinical features The main therapeutic lines are directed to any associated lung infection and to the relief of anoxia if there is bronchial spasm adrenaline and aminophylline are used If there is any cardiac irregularity digoxin is indicated.

Pathological emphysema (chronic hypertrophic type)

Both lungs one lobe or a segment of a lobe may be affected by emphysema obstructive compensatory or congenital in origin the term indicates over inflation and dilatation of the alveoli and distal parts of the bronchioles If compensatory emphysema is excluded

for the moment from consideration. the condition is a progressive one in which the elastic tissue of the alveoli atrophies, recoil is lost and eventually destruction of the alveolar walls leads to the formation of large conglomerate air sacs, blebs,* bullae or giant cysts which may become so large that by their pressure effects they impair the efficiency of the neighbouring lung tissue The function of the lung becomes progressively impaired, because although air enters the distended alveoli and pulmonary blood circulation is maintained, the exchange of gases between the two is seriously impeded

Bilateral acquired emphysema

Emphysema may result from frequent repeated and sudden rises of intrabronchial pressure when the expiratory phase is increased against a closed glottis, as in the coughing of chronic bronchitis and asthma, during these attacks the terminal bronchioles widen and the air pressure within them is increased suddenly when the glottis closes and air becomes imprisoned in the lobules, if there is scarring or oedema of the small bronchioles, their calibre is further decreased by the normal constriction that accompanies expiration, so that a valvular mechanism develops and entraps air in the alveoli The distension of individual alveoli may be partly relieved by the air drift from the pores in the alveolar wall sacs to adjacent lobules (the collateral ventilation of van Allen and Lindskog, 1931) Not only should this mechanism relieve tension but it would prepare the way for the further air entry of oxygen into the over-distended alveoli

Emphysema developing as a result of bronchial or bronchiolar disease, as after scarring from old tuberculous disease, may be segmental, lobar or generalized with bullous formation. Bullous and bleb formation is a common cause of spontaneous pneumothorax, and is often responsible for a "spontaneous" pneumothorax complicating an artificial pneumothorax induced as treatment for pulmonary tuberculosis but quite apart from this severe complication, the emphysematous area may cause significant symptoms severe enough to demand surgical treatment of the affected area This will be considered later

In generalized emphysema the chief defect in the pulmonary physiology depends on the loss of lung elasticity, the lung parenchyma becomes over-distended and cannot collapse properly in expiration, so that the residual and functional residual air becomes increased with consequent lowering of the reserve and complemental air volumes The chest wall movements are poor especially as the diaphragm becomes depressed and flattened and the intrapleural pressure becomes less sub-atmospheric It is possible that over-distension of the lungs brings the Hering-Breuer reflex into play so that conscious dyspnoea aggravates the effect of the lowered arterial blood oxygen, the raised blood carbon dioxide and the poor lung function

Obstructive emphysema

Incomplete obstruction of a bronchus, lobar or segmental, may cause a temporary emphysema, occasionally the first indication that a tumour, a foreign body or tuberculous granulation is present. It is unusual to see radiographs of patients at this stage, for severe symptoms do not arise until the tumour has caused atelectasis as the result of fuller occlusion Exceptionally emphysema may be due to extrinsic pressure on a bronchus from a tumour, gland, or mediastinal enlargement Both lungs may be affected by tracheal obstructions

* Blebs were defined by Miller (1927) as subpleural collections of air which followed the rupture of distended alveoli bullae represented collections of entrapped air within the lung parenchyma Both are quite different from congenital lung cysts

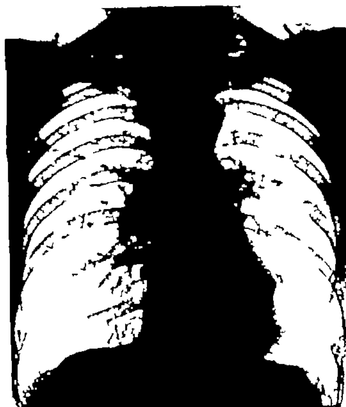


FIG. 21.1 (*a*).—Radiograph showing emphysema of left lower lobe associated with a left para-hilar mass. There is absence of vascular marking when compared with right lower lobe. Symptoms were of dyspnoea and haemoptysis and bronchoscopy showed a tumour partially blocking the lower lobe.



(*b*)



(*c*)

FIG. 21.1

(*b*) Photograph showing tumour in left main bronchus. The lung tissue shows the macroscopic appearances of gross emphysema. Pneumonectomy specimen.

(*c*) The diaphragmatic surface of left lower lobe showing emphysema with some well-developed bullae.

A mediastinal obstruction may affect one bronchus more than the other and when operations are in progress for the treatment of unilateral emphysema in infants this should be remembered

An infant was admitted to the Children's Hospital, Birmingham, with gross dyspnoea and stridor the left chest was bulging and left-sided emphysema was well seen on the radiograph (Fig 21 2), *which also shows considerable downwards displacement of the diaphragm* A bronchiogenic cyst in the posterior mediastinum behind the tracheal bifurcation with its main extension behind the left bronchus was the cause of the obstructive emphysema

Partial obstruction of a bronchus may be due also to inflammatory bronchial disease in bronchitis or tuberculosis In the latter disease the tuberculous endobronchitis not



Fig 21 2—Gross obstructive emphysema of the left lung in an infant, due to a mediastinal bronchiogenic cyst disclosed at operation
The cyst was pressing firmly against the trachea

infrequently causes complete collapse of an upper lobe and partial obstruction of the lower lobe, which becomes grossly distended as a result of the incomplete occlusion of its bronchus and because it undergoes compensatory emphysema to fill in the thoracic space previously occupied by its now atelectatic companion Obstructive emphysema due to obliterative bronchiolitis is commonly seen in patients with bronchiectasis At operation areas of the diseased lobe may be grossly emphysematous because of the entrapped air it is now a commonplace observation that even after the bronchus to such a lobe showing both bronchiectasis and emphysema has been divided and the clamp on the distal end has been released deflation does not follow These emphysematous areas may communicate through pores in the bridges of lung tissue with adjacent segments of healthy lung from which they become ventilated They are usually devoid of anthracotic pigment

Localized emphysema, as the result of the great tension developing in the emphysematous cysts, may compress and cripple the remainder of the lobe or lung These giant cysts can be treated, occasionally by phrenic nerve paralysis but more commonly by local,

segmental or lobar resection occasionally large cysts may be opened and the bronchial communication closed by sutures

Compensatory emphysema

When the intrathoracic space on one side has been diminished because of disease or surgical removal of one area the remaining healthy tissue will expand to avoid the reduction of space-occupying lung this commonplace finding in a chest X ray where there is translucent emphysema of an upper lobe is often the first indication that collapse of the lower lobe is present On the left side of the chest the atelectasis of the lower lobe as it lies behind the heart may be overlooked if the associated emphysema of the upper lobe is not noted



FIG *1 3—Emphysema at both bases.

There is a obvious collapse of the right lower lobe the partial collapse of the left lower lobe i concealed by the heart shadow Bronchography demonstrated bronchiectasis in both collapsed lower lobes.

If a diseased part of a lung which has lost alveolar function recovers rapidly e g pneumonia massive temporary collapse of a lobe the emphysema will disappear but in long-standing disease the over-distension of the aerated portions remains permanent

If the whole lung of one side is congenitally absent or deficient (agenesis) or has been surgically removed the contralateral lung over-distends hypertrophies and pushes the mediastinum over to fill in the dead space of the empty pleural cavity

The dangers of compensatory emphysema passing on into true pathological emphysema cannot be discounted although lobectomy and pneumonectomy have been performed for many years we still lack evidence as to the ultimate condition and function of the remaining lobe or lungs Experimental evidence based on the inspection of lungs after pneumonectomy and the autopsy reports on patients who have succumbed years after excision operations shows that the passing of compensatory emphysema to hypertrophic emphysema with loss of elasticity bullous formation and obstruction of the peri alveolar capillaries is a slow

process If the excisions are done at a young age the emphysema probably remains truly compensatory and it is possible that the remaining lung or lobes may show true hyperplasia This applies also to the sound lung in patients with agenesis The surgical correction of compensatory emphysema after pneumonectomy by thoracoplasty, pleural filling with non-absorbable material, phrenic avulsion, and pneumo-peritoneum has been discussed in Chapter 12

Cournand and others (1950) have published an important paper on pulmonary circulation and alveolar ventilation—perfusion relationships after pneumonectomy, in addition to measurements of the lung volumes, the maximum breathing capacity, the distribution



(*a*) (*b*)

FIG 21 4

This woman of 39 years complained of dyspnoea which was not sufficient to prevent her from carrying out all her household duties and she had four healthy children

The heart was so displaced to the left and posteriorly that the maximum cardiac impulse was in the scapular line The whole of the right lung is grossly emphysematous and its middle lobe fills the left hemithorax

The bronchograms demonstrate agenesis of the left lung

of tidal air throughout the lung, ventilation and of arterial blood oxygen saturation under varying states of activity, they added observations made from cardiac catheterization and the measurements of partial pressures of carbon dioxide and oxygen in the arterial blood They studied 16 patients after pneumonectomy carried out for a variety of pathological states and at widely differing ages A mild degree of pulmonary hypertension developed in all after mild exercise and this may be severe under strenuous tests, but they pointed out that electrocardiographic studies did not indicate right ventricular hypertrophy in these patients If pneumonectomy was followed by distension of the remaining lung, thoracoplasty was advisable, but evidence of distension was by no means inevitable in the absence

of thoracoplasty and a thoracoplasty which caused a severe scoliosis in itself could be followed by pulmonary dysfunction

Compensatory emphysema as an aid to cavity closure in pulmonary tuberculosis

The idea that cavities close as a result of complete occlusion of the cavity-draining bronchus is based partly on the assumption that the lung tissue around the disappearing cavity is healthy enough not only to re-expand but to develop compensatory emphysema. The valvular mechanism present in the bronchus draining tuberculous tension cavities is either changed into a complete block or becomes fully patent both in inspiration and expiration the cavity may close rapidly and this process is aided by the over-distension of surrounding healthy alveoli

Congenital causes of emphysema

Congenital causes of emphysema as distinct from true intrapulmonary cysts lined by bronchial epithelium may be associated with agenesis of a lobe or lung (Fig 21 4) with deficient cartilage formation in a lobar bronchus (Fig 21 5) or with congenital bronchiolectasis or alveolar dysplasia (Fig 21 6)

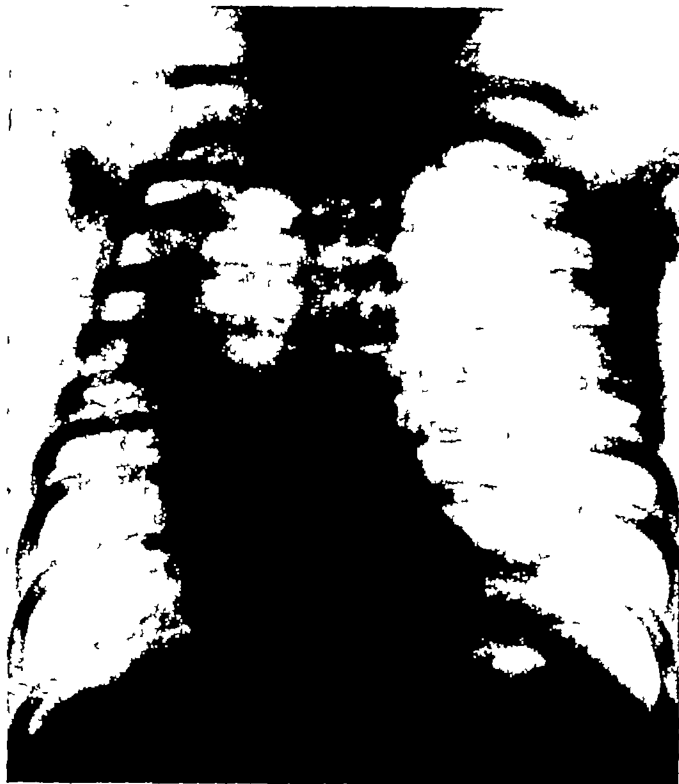
A few patients of the following type have been seen at the Children's Hospital Birmingham

A. S a female infant had suffered from periodic attacks of dyspnoea since birth When first seen in August 1947 at the age of three months she was underweight and dyspnoeic the apex beat was displaced to the right and the left chest was bulging and tympanitic on percussion The radiographic appearances (Fig 21 5 (*a*)) were startling with a grossly emphysematous left upper lobe which had produced pressure collapse of the left lower and of the right upper lobe with great displacement of the mediastinum In the following two years existence was precarious In August 1949 the radiological condition was unaltered and surgery was regarded as offering the only hope of relief

A lipiodol bronchogram (Fig 21 5 (*b*)) revealed a normal right bronchial tree a small but normal left lower lobe and an emphysematous left upper lobe into which lipiodol would not enter although a bronchial stump was present A left thoracotomy was performed and as soon as the pleural cavity was entered the left upper lobe grossly distended and emphysematous ballooned out of the wound it was removed by dissection lobectomy (Fig 21 5 (*c*)) The bronchus consisted of fibrous tissue only with a few scattered areas of cartilage As soon as the anaesthetist increased the intratracheal pressure the lower lobe re-aerated and two months later it almost occupied the complete left hemithorax The child has had no further dyspnoea and has developed normally

Another type of emphysema in infancy is represented by a rare group in which the terminal bronchioles open into defective alveolar tissue and they may be regarded as congenital bronchiolectasis and alveolar aplasia The following history represents an example of this group

C B an infant of a few days, was admitted in extreme dyspnoea and cyanosis The radiographs of the chest (Fig 21-6) revealed an advanced degree of emphysema of the right middle lobe The remainder of the right lung and the upper lobe of the left lung were compressed. In the hope that the condition was due to cartilage deficiency of the right middle lobe bronchus a thoracotomy was carried out immediately the chest was opened the middle lobe bronchus bulged out of the wound The distended lobe was removed but unfortunately the infant died without any relief having been afforded Dr Baar reported on the histology of the middle lobe as follows Middle lobe of right lung 9 × 6 × 1 5 cm in size The lobe presented the appearance of acute emphysema and in addition there were subpleural vesicles of interstitial emphysema On dissection cystic spaces up to 4 mm in diameter were found Histological examination revealed dilatation of respiratory bronchioli alveolar ducts and alveoli There was generalized emphysema and in addition larger cystic spaces the walls of which had the character of alveolar walls and scattered small solid areas in which there was a failure of differentiation of alveoli





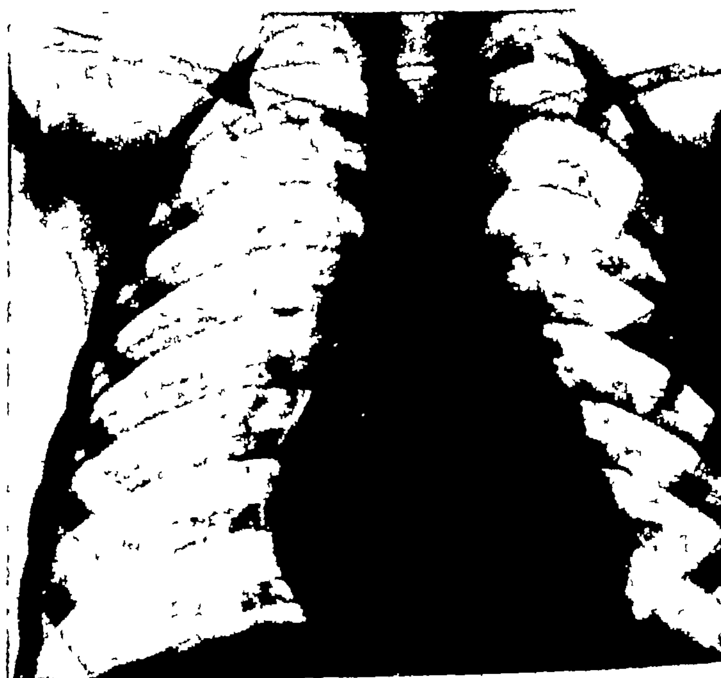
(*a*) (*b*)

Fig 21 5

(*a*) Radiograph of infant aged 3 months showing gross emphysema of left upper lobe with pressure colla[p]se of the left lower and right upper segments

(*b*) Lipiodol bronchogram at the age of 2 years.
Gross emphysema of left upper lobe There is no filling of the left upper lobe bronchus





(c) (*d*)

Fig 21 5

(c) The emphysematous left upper lobe (13 cm) lobectomy specimen
(*d*) Radiograph of the chest a year after left upper lobectomy

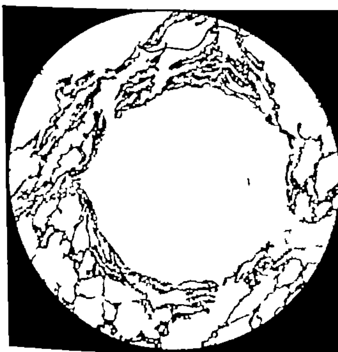




(*a*) (*b*)

Fig 21 6

(*a*) Congenital "emphysema" of right middle lobe.
Postero-anterior radiograph of chest
(*b*) Lateral radiograph showing distended right middle lobe





(*c*) (*d*)

Fig 21·6—Histological appearances of excised middle lobe (see text)

Acquired giant emphysematous cysts

Localized emphysema may cause serious symptoms and disability because the tension in the " cysts " may cripple the remainder of the lung or lungs, as in the case of the children just described but more usually it is in patients with bilateral emphysema that large bullous cysts occasion exacerbations of dyspnoea, these air cysts may follow a slit-like tear into the wall of an adjacent bronchus which allows air to enter the huge sac in inspiration but leaves it entrapped in expiration when the opening becomes valvular The rupture of emphysematous blebs and bullae accounts for some examples of spontaneous pneumothorax When the lobe or lung is occupied by smooth thin-walled " cysts " without evidence of lung or pleural inflammation a congenital origin may be possible, although inflammatory obliterative bronchitis is the common cause once the condition is present the continued distension of alveoli and the rupture of one distended alveolus into another may produce such tension that the bronchiole supplying the affected area may itself give way to leave a slit-like opening into an area of bullous formation (Allison, 1947)

Operative attacks on such giant emphysematous cysts may be required when the enlargement is causing grave dyspnoea in an already crippled patient or when they rupture to cause a chronic spontaneous pneumothorax (Brock, 1948, Brewer, 1950) Dugan and Samson (1951) have described their experiences with 15 operations for this condition in which considerable relief was provided with one immediate post-operative death

Indications for surgery in emphysema

Many patients with bilateral or unilateral emphysema though partly incapacitated can lead normal lives, these patients rarely come for surgical attention but in a few instances the progressive enlargement of emphysematous blebs or bullae may cause spontaneous pneumothorax or severe dyspnoea As already mentioned, in recent years surgical attention has been directed to a small group with large air-containing cysts which by their high tension and because they provide large dead-space reservoirs cause a completely disabling dyspnoea These cysts are usually multiple, but may be single Quite often the apparently " single " cyst is the dramatic feature of a patient's radiograph and distracts attention from the generalized emphysema

The physiological aims in surgical treatment are to relieve local tension effects or to decrease the residual air and so diminish the inadequate ventilation of alveoli. At first sight it would appear to be foolish to sacrifice any lung tissue, but in the resection of grossly emphysematous tissue it must be remembered that not only is the resected tissue non-functional, but it is often an actual embarrassment to the respiratory physiology In emphysema the pathological process has produced great destruction of elastic tissue and of the alveolar walls, these latter become distended (because they cannot recoil owing to elastic deficiency) and rupture into each other to produce gross air cysts

In addition to this serious defect, the subdivisions of the lung volume are greatly altered, the chief differences being an increase in residual air because the lung does not empty properly at expiration The reserve air is apparently decreased, although Herxheimer (1949) suggested that this may not be true when there is a lowly placed diaphragm and that a real increase in reserve air can be unmasked by giving adrenaline which relieves an associated bronchial spasm The total vital capacity is decreased because the residual air is in excess of the normal and the intrapleural pressure, being less sub-atmospheric than normal (because of the loss of lung elasticity), causes a further diminution in the volume of complemental air

In direct attacks upon local areas of emphysematous disease the surgeon can only hope to correct (and that in quite exceptional cases) the defective gaseous composition of the blood and to decrease the amount of residual air In large tension cysts with a valvular mechanism which comes into play in expiration this impediment can be overcome by removal of the cyst or cysts or by obliterating the valve-like mechanism or in a few cases by interruption of the phrenic nerve

Indications for phrenic nerve interruption (Allison)

In some patients dyspnoea and pain may result from the tension within bullous cysts that have been produced by chronic cough and infection In Allison s first recorded patient who had had a chronic cough with little sputum for many years exercise such as bending cycling or digging produced attacks of breathlessness and a feeling of fullness at the right base and in the axilla the symptoms had started quite suddenly On the assumption that an area of over inflated lung could so interfere with the Hering Breuer reflex that the full depth of inspiration could not be achieved the employment of phrenic nerve crush was advised the radiograph showed an area of bullous formation in the right costo phrenic angle and it was considered that the piston like action of the diaphragm played a large part in inflating this segment of the lung

A right phrenic nerve crush at once removed all symptoms a psychological result was an unlikely explanation because four months later he complained of a return of symptoms and the right diaphragmatic leaf was seen to be working again a phrenic avulsion led to complete loss of symptoms and he was still well four years later

That actual improvement in respiratory function may follow phrenic interruption as well as relief of symptoms was suggested by the report of a man of 53 who had bullous cysts at both bases attacks of dyspnoea and of right basal pain referred to the shoulder suggested the use of phrenic interruption while on the operating table in the position for the procedure the vital capacity was taken and estimated at 1 700 ml after the nerve had been crushed under local anaesthesia the figure rose to 2 300 ml

Excision or obliteration of cystic areas

As already mentioned an indication for this radical procedure exists in some patients with recurrent or chronic spontaneous pneumothorax and this will be considered later Apart from the complication of repeated or chronic pneumothorax these cystic areas may require excision for the reasons given above

Air cysts with large bronchial communications

The larger the communication between the air cysts and the bronchi the less is the disturbance of function correspondingly surgery is less frequently required The chief disadvantage to the patient is over ventilation of lung areas that are poorly perfused with blood The dead space air is increased In patients with unilateral cystic disease pneumonectomy is indicated chiefly for the relief of infection but may improve lung function by removing a large area of lung tissue associated with very inefficient gas exchange After operation although the total lung volume will be diminished the maximum breathing capacity improves The surgical problem in this group is really that of the treatment of bronchiectasis and is judged by the same standards

Air cysts with poor or intermittent communication with the bronchus These provide a far more crippling effect than those with wide open communications Dyspnoea and asthmatic attacks are important features Severe ventilatory insufficiency is due to

interference with the bellows action of the lung which does not deflate on expiration and the tension within the cyst may be high Lung volume and the maximum breathing capacity are reduced Spirography discloses evidence of expiratory obstruction and air trapping, the oxygen uptake is diminished.

If the remainder of the lung tissue is not too emphysematous great relief may be afforded to these patients by excisional surgery or by the obliteration of the cystic area by suture after they have been opened and their valvular openings into the bronchi obliterated Physiological studies have been made to show the improvement that follows surgery in this group of patients (Baldwin, Harden, Green, Cournand and Richards, 1950)

An example of an improvement in the respiratory physiology produced by the obliteration of a giant air cyst is provided by the following history

Mrs M, aged 29, was admitted to the Queen Elizabeth Hospital under Professor Melville Arnott For ten years she had suffered from difficulty in breathing, persistent cough and asthma A year before admission she had a sudden sharp haemoptysis The sputum was persistently negative for tubercle bacilli She was pale, thin and easily tired and had lost weight steadily over the last three years She was unable to perform the lightest home duties She presented the clinical and radiological features of a patient with gross bilateral emphysema The right upper lobe of the lung was occupied by a giant emphysematous cyst (Fig 21 7 (*a*))

Although the patient was an obvious respiratory cripple it was decided to attempt some palliation of her dyspnoea by surgery In March 1945 the right chest was opened. a large cyst was present in the right upper lobe and the pressure within it was positive The thin cyst wall was incised a valve-like slit was seen in a small bronchus in the medial wall of the cyst This bronchial opening was sutured and the cavity of the cyst obliterated by a series of interrupted sutures after a portion of it had been excised Emphysema was present throughout the whole of the right lung The chest was closed with tidal drainage for 48 hours

The post-operative course was easier than had been anticipated a collapse of the right lower lobe was treated the day after operation by bronchoscopic suction The lung re-expanded rapidly

Dyspnoea was considerably reduced and the operation was of some palliative value

She was re-assessed eight months after the obliteration of the cyst The general condition was improved

The arterial oxygen content was 92 per cent

The vital capacity 2 2 litres (0 04 litres greater than the pre-operative measurement)

Residual air T L V. ratio = 0 521 (it was 0 581 pre-operatively)

Another example is illustrated by the following

A man of 40, a moulder by trade, had suffered from increasingly severe asthma, which at times was incapacitating He was troubled by a chronic cough and pain in the right lower chest for years before the asthmatic attacks developed Radiography (Fig 21 8) revealed emphysema of both lungs but the emphysema at the right base was associated with a large bullous cyst The bronchogram (Fig 21 8 (*b*)) shows a collapsed right middle lobe, a well-developed anterior segment of the upper lobe there is no filling of the posterior basal segment of the right lower lobe which corresponds with the area of the giant cyst

The constant cough may have followed the collapse of the right middle lobe and the cough may have played a part in the development of the emphysema The posterior part of the right diaphragmatic leaf is depressed Unfortunately no physiological studies were carried out at the time In 1947 the lower lobe was resected the large bulla connected through a thin slit with a neighbouring bronchus The phrenic nerve was paralysed He has had no more " asthma " or right basal pain since the operation and is greatly improved but still has some dyspnoea

These air-distended cysts are not unlike the traumatic cysts seen after some gun-shot wounds of the chest As the missile traverses the lung it leaves a blood-filled track especially well seen when the metal is lodged in the lung itself Later, as the clot retreats, small bronchial openings into the previously solid cone may cause distension cavities that may



(a)



(b)

FIG 21 7—Pre- and post-operative radiographs after operative obliteration of giant cyst of the right upper lobe in a woman of 29 years with severe bilateral emphysema.



(a)



(b)

FIG 21 8

(a) Giant emphysematous cyst of right lower lobe in a man of 40 years.
(b) Bronchogram. The middle lobe is collapsed and no lipiodol has entered it nor the posterior basic segment of the lower lobe which is the site of gross emphysema.

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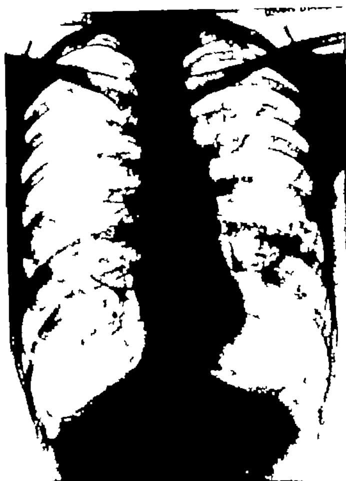
Residual air T L V ratio = 0 521 (it was 0 581 pre-operatively)

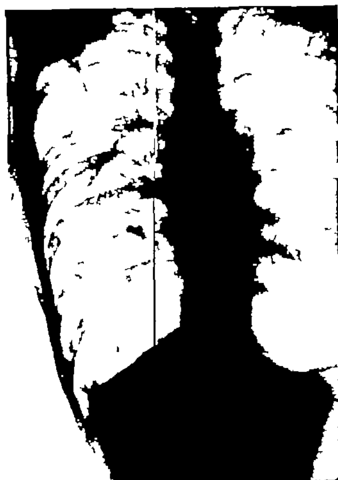
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(a) (b)

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(a) (b)

FIG 21 8

(a) Giant emphysematous cyst of right lower lobe in a man of 40 years.
(b) Bronchogram The middle lobe is collapsed and no lipiodol has entered it nor the posterior basic segment of the lower lobe which is the site of gross emphysema.

persist for months, as in the example illustrated in Fig 21 7 These lesions have been studied especially by Hodson (1946)

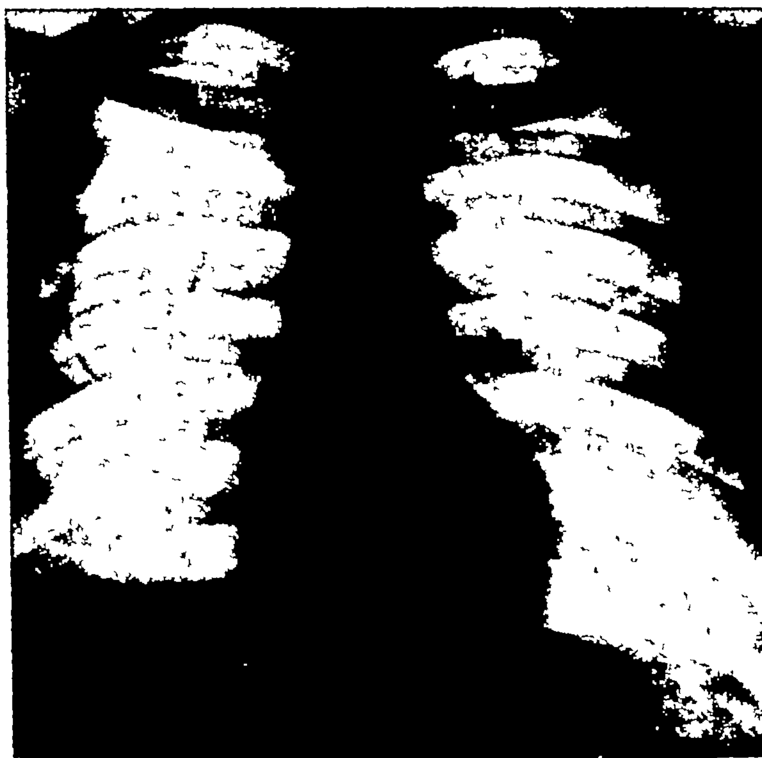


Fig 21 9—Traumatic cyst of right upper lobe

The translucent cavity noted was seen to develop in the course of four months during the stay of the soldier in a Military Hospital in Italy The right upper lobe had been traversed by a perforating bullet wound

Spontaneous pneumothorax

In most instances this takes the form of one single attack (simple spontaneous pneumothorax) about 60 to 70 per cent develop in non-tuberculous patients The complication develops in patients without obvious pulmonary disease (30 to 40 per cent) and the remaining group have a wide range of lesions including emphysema, asthma, bronchitis, tuberculosis, bronchiectasis, neoplasms, and staphylococcal lung abscess In the tuberculous group adhesions are often present and this is especially noteworthy in the patients who develop a spontaneous pneumothorax into a therapeutically induced artificial pneumothorax (the tuberculous cases often develop fluid, a quite exceptional finding in the non-tuberculous group)

From evidence obtained at thoracoscopy, adhesions are often absent in patients with normal lungs or emphysematous lungs or when congenital cystic disease is present An important point is that spontaneous pneumothorax developing in the absence of serious pulmonary lesions is usually seen in a younger age group than when it complicates lung disease and that this benign group is far commoner in males Sudden exertion of a violent nature may be apparent in the history of the condition, which is diagnosed by the acute onset of pain and dyspnoea, associated with a tympanitic note on percussion, with possible displacement of the mediastinum and a characteristic radiographic appearance But a less dramatic type exists in which the diagnosis is made during a routine radiography The result of treatment by conservative measures is satisfactory in a large group, aided by withdrawal of small quantities of air if dyspnoea is present, and absolute bed rest, the lung usually re-expands in two to four weeks Occasionally the collapsed lung becomes obstructed

by intrabronchial secretions in these circumstances bronchoscopic aspirations may lead to rapid re-aeration

Surgical measures are indicated in the group of recurrent or chronic spontaneous pneumothorax which will be considered below If the radiograph in the patient with a benign spontaneous pneumothorax reveals no pulmonary or pleural lesion thoracoscopy is not necessary if a spontaneous pneumothorax complicates a therapeutic pneumothorax and adhesions were seen on the radiograph before the leak developed thoracoscopy for the division of the adhesion is indicated division of suitable adhesions not only prevents the risk of a chronic pneumothorax but may stop the formation of pleural effusion It is not





(a) (b)

FIG 21 10

(a) Radiograph to illustrate a spontaneous pneumothorax with total lung collapse
(b) Radiograph two weeks later Air had been aspirated on two occasions.

uncommon at such operations to note that the lung has torn at the pulmonary base of an adhesion In nearly all the patients in this group who have been thoracoscoped sub pleural blebs in areas of old lung disease are seen and usually the pneumothorax should be abandoned

Chronic or recurrent spontaneous pneumothorax

The lung in these patients may remain collapsed for many months (15 months in 46 cases published by Brock) and the disability is severe and crippling if not treated adequately If re-expansion has not taken place within four to six weeks a full investigation in which thoracoscopy is essential is indicated because almost without exception the condition can be corrected.

In the largest published series of recurrent and spontaneous pneumothorax, Brock (1948) found that persistent leak of air into the pleural cavity was noted in 25 patients with emphysema (12 with emphysema, 13 with "bullous" emphysema), 8 in asthmatics with emphysema and bronchitis, 15 times in association with small bullae mostly at the apex, and in 11 patients with large solitary bullae or congenital cystic disease. The incidence of bilateral recurrent or spontaneous pneumothorax is by no means insignificant as Brock studied 15 bilateral alternating cases and 8 in which both sides were involved simultaneously

The need for adequate treatment The patient with recurrent pneumothorax is at a grave disadvantage from a social and economic point of view The dread of recurrence and the handicaps imposed by advice that compels a regime of extreme quiet are heightened by the ever-present danger of a spontaneous pneumothorax on the other side the patient with a chronic persistent pneumothorax is usually a permanent or semi-invalid In distinction to the group who suffer only one pneumothorax, the benign simple type, the recurrent or chronic group include many people with underlying lung disease, the cause of the complication itself, and this pathological basis indicates that the further loss of respiratory function is serious Chronic spontaneous pneumothorax is, moreover, far commoner in the age group over 30 when respiratory reserve is less elastic and adjustable and severe dyspnoea often reflects the complication of collapse added to a frequently pre-existent bronchitis and emphysema The patient is usually very thin with a poor physical capacity for work

Investigation and treatment The demand for a full diagnostic technique is supported by the need for as accurate an assessment as possible of the underlying disease The history of asthma (perhaps now no longer in its true form) and the physical and radiological examination will often present a picture of emphysema of the general or bullous type invading one or both lungs The radiological examination of the pneumothorax must be scrupulous, for at times the differentiation of this from a huge, giant tension of the lung may be difficult, the danger of such an error is that a needle introduced into a supposed pneumothorax may puncture the cyst, possibly producing a fatal tension pneumothorax. Moreover the best treatment of a giant cyst is often by thoracotomy and removal which will allow the rest of a compressed lung to re-expand satisfactorily

The pre-operative investigations must exclude tuberculosis and bronchiectasis, the latter disease is a far commoner accompaniment than tuberculosis and it may not be diagnosed unless a bronchography is done, especially on the left side, the lower lobe may be collapsed into a small retro-cardiac shadow and in the emphysematous upper lobe, bullous formation may have been the cause of the leak

Thoracoscopy This examination is of value Direct inspection of the lung and pleura may expose the exact cause of the spontaneous pneumothorax and the actual site of the leak Emphysematous blebs or bullae, with or without associated areas of scarring, large thin-walled cysts possibly congenital in origin, or adhesions leading to a pathological area of lung tissue are commoner findings. Surprisingly healthy lungs may be viewed and the explanation of leaking from such is difficult Brock has gathered evidence that in this group of patients the porosity of the lung is indicated by the appearance in one or more sites of white bubbles on the surface, the appearance well described by him as "cuckoo spit" In these patients the gentle pressure of a probe on the lung may produce areas of leakage

The thoracoscopic appearances enable the surgeon to decide on the appropriate treatment, which may be by surgical exploration or by chemical pleurodesis The safest and, according to Brock the most effective treatment, the production of chemical pleurodesis, may be used for those patients with generalized emphysema, porous lungs and apical bullae

associated with localized scarrings Large bullous cysts of congenital type or due to over distension in areas of localized emphysema are often best treated by lobectomy local excision or direct suture of the entering bronchus with its associated tear When adhesions leading to a tear in the lung at their base or to areas of small bullous formation are seen their division by the cautery at the time of thoracoscopy may produce rapid permanent re expansion of the lung at the same time the affected surface of the lung can be painted with 10 per cent silver nitrate

If pleural adhesion is produced in patients with large cysts or bullae the check valve mechanism producing the bullae is left unaffected and progressive distension of these cysts



(a) (b)

FIG 21 11

(a) Bilateral emphysema with a right chronic spontaneous pneumothorax in a man of 52 years

He was severely dyspnoeic and orthopnoeic The middle and lower lobes are actively collapsed by the pressure of the positive pneumothorax and the upper lobe is grossly emphysematous and occupied by large bullae

(b) Three weeks after thoracotomy

Three large giant emphysematous bullae of the upper lobe were opened all had bronchi with slits in them opening into the cyst The bronchial tears were sutured and the cysts locally excised and obliterated by suture. Lung re-expansion was rapid and the dyspnoea greatly improved

may produce a severe crippling of the respiratory function by the effects of pressure on the remaining lung tissue and by the increase of dead space air since the normal respiratory exchanges do not take place in such distended sacs

Treatment of chronic or recurrent pneumothorax The choice lies between thoracotomy the artificial obliteration of the pleural space or the division of adhesions by thoracoscopy

Brock carried out major surgical resections in 8 patients divided adhesions in 2 and performed chemical pleurodesis in 53 He reserved thoracotomy for patients with cysts or large bullae Brower (1950) prefers thoracotomy to pleurodesis because it provides a true

account of the underlying pathological condition, which is usually due to a leak from diseased lung tissue such as congenital cysts, emphysematous bullae, scar tissue, or covered by a thickened visceral pleura, which will not allow the rent to seal, he also indicates that chemical pleurodesis leads to considerable loss of lung function as estimated by physiological studies Fifteen patients were operated on without death and with great improvement the surgical procedures employed consisted of resections of grossly diseased areas, division of adhesions or decortication of a thickened envelope lying on the visceral pleura My own preference is for thoracotomy and I rarely practise chemical pleurodesis

Surgery in pulmonary emphysema : Summary

Surgical measures for the relief of emphysema are limited to the treatment of spontaneous pneumothorax when it complicates the disease, to the removal or obliteration of

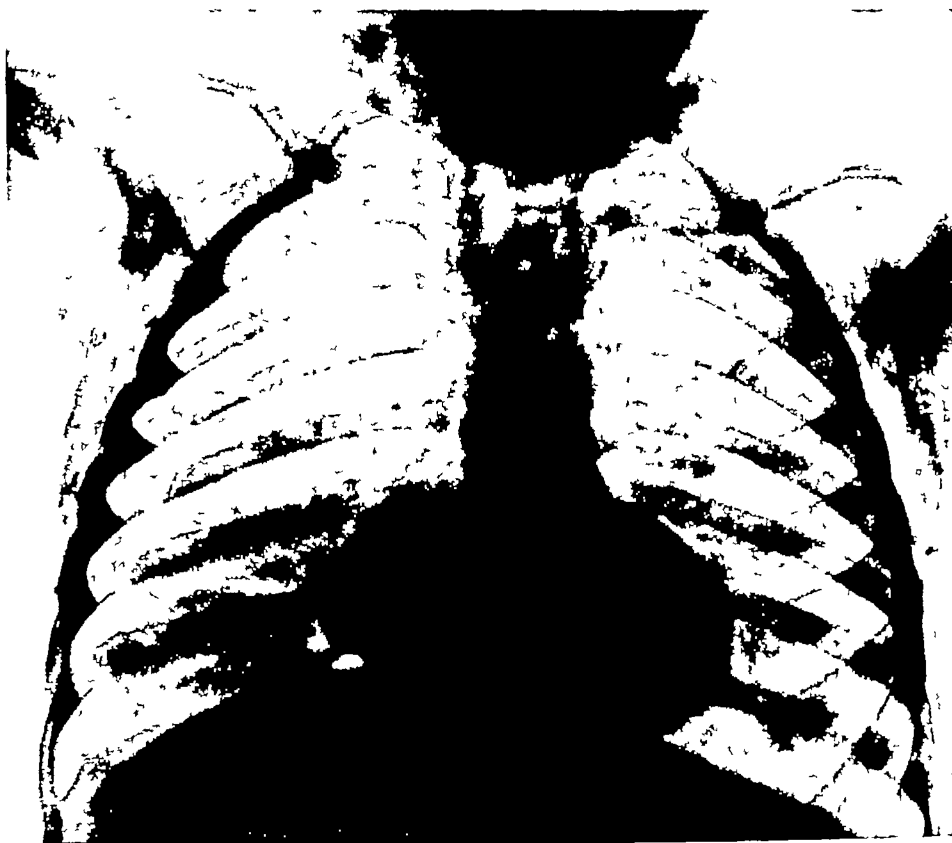


Fig 21 12 —Pneumothorax and surgical emphysema developing as a complication of broncho pneumonia in a child

segments or lobes of the lung affected by bullous emphysema that are exaggerating the symptoms, and embarrassing the remainder of a diseased but functioning area of lung tissue, and to collapse measures designed either to diminish the capacity of the thorax after pneumonectomy or to remove the piston action of the diaphragm by phrenic nerve interruption in rare examples of bullous emphysema when over-distension is occurring predominantly in the inspiratory phase of respiration

Interstitial emphysema of non-traumatic origin

After crush injuries, gun-shot wounds or thoracotomy, surgical emphysema is common (see pp 89, 519, and Fig 5 1) Quite exceptionally as the result of severe cough, as in broncho-pneumonia or whooping cough, a pneumothorax may develop and if a bronchus

or bronchiole of any size has given way interstitial emphysema may follow the air escaping along the line of the bronchus into the mediastinum and spreading beyond the chest area The condition is serious suffocative symptoms being associated sometimes with a distending pressure in the mediastinum which obstructs the flow in the thin walled veins so reducing the venous return to the heart Mediastinal emphysema is indeed the only type of surgical emphysema that in itself is serious Relief may be afforded by a small transverse incision above the sternum which opens up the entry to the mediastinum so that the entrapped air can escape The underlying lung infection is treated by antibiotic therapy oxygen therapy is used and intrapleural collections of air are removed by the pneumothorax apparatus or by a needle left in the pleural cavity and connected to an under water sealed drainage system

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CHAPTER 22

PULMONARY HYDATID DISEASE

Though endemic in some areas (Australia, Argentine, France, Iceland, Yugoslavia) hydatid disease of the lung appears in the practice of thoracic surgery throughout the world In this country many of the patients come from Wales, but some are seen sporadically in all areas The differential diagnosis may be difficult but is important Surgical treatment is safe and curative in most instances

In the human the cystic stage in the life cycle of the echinococcus is seen primarily in the lung in 15 to 20 per cent of the cases, the liver being the commonest harbouring site , not infrequently multiple cysts develop in the liver and one or both lungs at the same time , probably these examples of multiple cysts are not referred commonly to a thoracic surgeon and I have only operated (knowingly !) on two patients out of 40 who had cysts other than in the thorax, one having many cysts in the liver (a Yugoslav), and the other a cyst of the spleen (a Welshman, Fig 25 3) There may be more than one cyst in the lung Bilateral disease of the lungs (Fig 22 3) is not uncommon and Barrett by 1947 had operated on six such patients Widespread dissemination of cysts following rupture into a large blood vessel or the heart (hydatid embolism) has been reported on many occasions but is not common

Natural history of pulmonary hydatid disease. There being no specific remedy for echinococcal disease, natural cure can only result from expectoration through the bronchus or by calcification after the cyst has died In addition to endobronchial rupture the parasitic cyst may burst into the pleura or pericardium, carrying not only the risks of anaphylaxis, but of daughter cyst formation (In one patient for whom lobectomy was done for a complicated, infected ruptured cyst of the right lower lobe of the lung, over a hundred daughter cysts lay in the pleural cavity or mediastinum) The hope that cure will follow expectoration is not sufficient grounds for advising expectorant treatment, for over 20 per cent of the patients die from asphyxia or anaphylaxis during this natural sequel and in many the coughing up of the mother cyst is incomplete and symptoms may recur later The incidence of suppuration in the lung parenchyma after spontaneous evacuation is high, the clinical picture being one of lung abscess , pleural effusion and empyema may follow Intrapleural rupture causes a high death rate from anaphylactic shock and tension pneumothorax

The undoubted fact that complete cure has followed expectoration is no support for a conservative, non-surgical attitude because the death rate from nature's attempt at cure exceeds any surgical hazard Barrett (1947) records only one death after operation for 50 cysts and there has been one death in a personal series of 40 operations

Diagnosis. Frequently symptoms are minimal or absent, an ovoid clear opacity being discovered on routine radiography but many patients come with thoracic pain, haemoptysis and cough Small haemoptyses are undoubtedly the commonest symptoms Dyspnoea is occasionally severe and the cause of the patient seeking relief , the explanation of the dyspnoea is difficult, but may be due to the setting up of the Hering-Breuer reflex, the result of local lung distension affecting the vagal nerve terminations, or possibly is anaphylactic Severe breathlessness may exist when the cyst is quite small A man of

46 years was referred to me because of dyspnoea and the presence radiologically of a small opacity in the right lower lobe a negative search was made for a primary growth on the assumption that this might be a metastasis It was in 1937 and at operation the char acteristic surface changes in the visceral pleura consistent with hydatid disease were over looked a lobectomy was done the diagnosis being made post-operatively The patient recovered well, but the feature of chief interest was complete disappearance of dyspnoea the day after the lobectomy *Anaphylactic symptoms* such as skin urticaria tachycardia and shortness of breath are common.

If the cyst has ruptured into the bronchus the one certain diagnostic feature is the discovery of hooklets in the sputum none of the laboratory investigations provide anything approaching a 100 per cent diagnosis The Casoni skin test if active hydatid fluid is available gives a high incidence of positive reaction which is almost unfailingly present in the absence of complications the hydatid com plement fixation gives a positive result in from 80–90 per cent of cases An increase in the eosinophils in the blood may or may not be present and this finding is not of great diagnostic value

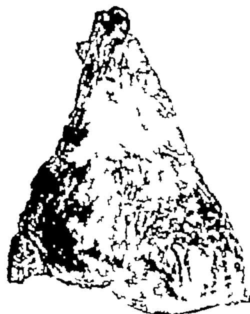


Fig 22 1 —A small hydatid cyst in apical segment of right lower lobe which had caused intense dyspnoea (Dr William Phillips patient)

Radiological appearances An uncomplicated hydatid cyst of the lung gives a slightly ovoid shadow of uniform density it is not truly circular as often stated and although the edges are clear-cut the out line may show indentation where the cyst is pressing against unyielding structures

When complications are present such as pleural effusion surrounding *pneumonitis* atelectasis or air within the peri-cyst the appearances are notably altered in the unusual event of the affected area of the lung being adherent to the parietal pleura the outer wall of the cyst appears to be straight If the patient is about to cough up the cyst through a small bronchial fistula the true cyst may become separated from the peri-cyst tissues and a cap of air appears about it (pneumo-cyst) (Fig 22 3)

After expectoration or surgical removal of a cyst a persistent cavity is left in the lung which may become partly filled with pus or fluid presenting an appearance like that of a lung abscess The tissue around the cyst occasionally shows calcification and this is usually regarded as a sign that the hydatid is dead (Fig 22 4) Inflammatory changes or atelectasis around a cyst may confuse the radiological diagnosis (Fig 22 5)

Since tumours of the lung or mediastinum such as bronchial carcinoma neurofibroma metastatic carcinoma often produce ovoid shadows they should be considered before a suggestion of hydatid disease is entertained

Surgical treatment Attempts at diagnosis or cure by aspiration are dangerous and foolish The surgical aims are to remove the mother cyst without providing any danger of secondary daughter cysts developing either from contamination of the pleura or as the result of incomplete removal of the laminated lining of the mother cyst and to avoid any danger of hydatid fluid escaping into the pleura or soft tissues of the chest wall Attempts

at aspiration break all these rules and from published experience the method is ineffective and has caused sudden death from pleural anaphylactic shock

The "two-stage" drainage operation is obsolete notoriously even a superficially placed cyst fails to cause dense pleural adhesions and Barrett has emphasized the difficulty of producing pleurodesis by chemical irritants Drainage of a cyst by marsupialization is obsolete because fixation of the lung to the parietal pleura by dense adhesion is uncertain Efforts to supplement the symphysis of parietal to visceral pleura by suture are highly dangerous because after drainage of the cyst a bout of coughing may tear the lung away from the parietes and produce a pneumothorax or more dangerous tension pneumothorax

With modern surgical technique and anaesthesia there is no case to be made against thoracotomy with complete exposure of the lung area containing the cyst or cysts, whether adhesions be present or not The cyst having been fully exposed three courses are open (1) Removal of the cyst completely after partial aspiration of its liquid contents * (2) Removal of the cyst entire without even the help of a preliminary decompressing aspiration (Barrett's manœuvre) (3) Lobectomy The last method (Fig 22 6) is reserved for those cysts with suppuration as a complication, associated with bronchiectasis or rarely as a later operation when, after successful extirpation of the mother cyst, infection has developed in the "sac" left after such an operation Lobectomy is occasionally advocated for a cyst placed at the base of the lower lobe in contact with the diaphragm

Removal of the cyst through a wide thoracotomy incision. As soon as the problem of the open surgically produced pneumothorax had been solved by good anaesthetic technique, surgeons throughout the world began to adopt this method In most of the patients the affected lobe shows a characteristic appearance, the adventitia of the cyst appearing as a white pearly-grey patch under the visceral pleura A hydatid cyst, like a lung abscess, usually presents on the surface of a segment and the so-called para-hilar ones are equally superficial, though the presenting area may be towards the mediastinal pleura, in the lower lobe the cyst may be closest to the diaphragm and this often gives the impression of great depth in site Before Barrett introduced the method described later the affected lobe was carefully packed off with saline swabs on which were laid pieces of gauze wrung out in 1 per cent formalin

The cyst is partially aspirated, the greatest care being taken to avoid any spilling of the crystal-clear contents which may contain scolices a small amount of 10 per cent formalin is then injected and no attempt made to remove the cyst for five minutes The needle having been withdrawn, the hole in the cyst and its adventitia is closed with a fine mosquito forceps While gentle traction is made on this forceps, a cautious incision is made through the adventitia till the germinal layer is exposed a small incision is made through this into the cyst, the remaining contents of which are aspirated by the sucker The flaccid cyst is then lifted out intact, with sponge-holding forceps an inspection of the cyst should show it to be intact except in the area previously entered by the scalpel A cavity in the lung is seen which may ooze a little blood

The obliteration of the cavity An attempt is made to obliterate the cavity of the pseudo-cyst by interrupted catgut mattress sutures These sutures must be passed with great care to avoid damage to large vessels that may lie nearby, the incision previously made through the thinned-out overlying lung parenchyma is then closed by sutures The anaesthetist re-inflates the lung and the chest is drained by apical and basal catheters, to which post-operative motor suction drainage is applied for 48 hours

* Leigh Collis has demonstrated clearly that by careful dissection the cyst with its adventitia can be excised intact with complete safety





FIG 22 2 FIG 22 3

FIG 22 2 —Radiograph of hydatid cyst in a Jugoslav soldier aged 25
It w s removed by open thoracotomy

FIG 22 3 —Bilateral hydatid cysts.
The one in the left lung show small cap of air the classical feature of a pneumo-cyst (Mr Ronald Edward patient.)

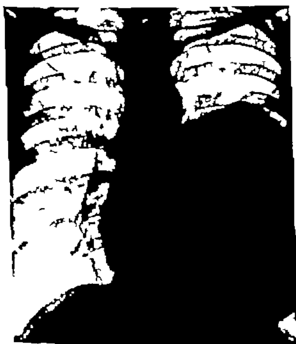




FIG 22 4 FIG 22 5

FIG 4 —Large hydatid cyst of left lower lobe with peripheral calcification above and below (Mr E G Dolton s patient)

FIG 22 5 —Hydatid yst of an apical segment of left lower lobe
A W [illegible] of [illegible] who came t the [illegible] year previou ly three ears before thi radiograph taken small haemopt [illegible] commenced, the patient rem ined persistently negativ for tubercle bacill Because of the doubtful diagnosis thoracotomy was done and the pical segment of the left lower lobe was removed the segment cont ined small hydatid cyst (Yardley Green H spital)

Barrett's manœuvre (Barrett, 1949) "A technique which offers good hope of success in the case of univesicular simple hydatid cyst is as follows the patient is given a general anaesthetic, and this is maintained after a cuff tube has been introduced into the trachea to make an airtight circuit The head of the table is lowered so that if the cyst ruptures into the bronchus the liquid drains from the lungs by gravity The appropriate hemithorax is opened, either by rib resection or an intercostal incision placed at about the level of the middle of the cyst, and the pleural cavity is opened widely with rib spreaders If pleural adhesions are present, they are divided so that the lobe which contains the cyst is free The affected lobe, or, where a giant cyst is present, the cyst, is then enclosed in a bag of thin mackintosh, made like a sponge bag, with strings at the top for gathering up the inlet, but the bottom cut open The bag is placed round the lobe containing the cyst with the strings at the hilum, and these are drawn up moderately tightly to encircle the neck of the lobe without impeding respiration in the lobe or the blood-supply The bottom of the bag is then opened out, brought through the incision, and spread out on the surface of the wound so that the affected part is inside a waterproof container The bag not only gives some protection against accidental rupture, but, later in the operation, is an excellent retractor The exact position of the cyst in the lobe is now ascertained and in most cases the adventitia will be seen on the surface of the lung as a patch of white membrane If the hydatid has not grown up to the surface, the lung is incised over the cyst, and down to the adventitia The stage is now set for removing the cyst

"The adventitia is partially incised by a straight cut with a knife The length of the incision should be about the same as the diameter of the cyst measured in the radiographs, and it should be placed towards the bottom of the cyst as the patient lies on the table The incision must be made cautiously, because as a rule the adventitia of lung cysts is not more than one-eighth inch thick The object is to form a crack in the adventitia and not to expose the laminated membrane throughout the length of the incision If the laminated membrane is exposed, it will be obvious because of its colour—white, faintly tinged with blue Once the laminated membrane has been exposed in one spot the incision in the adventitia can be extended by lifting it off the cyst and cutting with blunt-pointed scissors for about an inch No attempt should be made to expose the cyst widely

"The surgeon's job is now for the time being over, success now depends on not touching the parts until the cyst has been extruded from the lung This is achieved by the anaesthetist who steadily increases the pressure in the anaesthetic circuit so that little by little, over ten to thirty minutes, the adventitia cracks to the full length of the incision and the hydatid gradually falls out of the lung intact and lies in the mackintosh bag During this period there must be no attempt to hurry matters, and if the surgeon cannot be persuaded to leave well alone the safest instrument for him to use is a sterile houshold spoon of appropriate size

"Once the cyst has herniated out of the lung it lies in the bag by the side of the lobe which originally contained it The operation table should now be tilted towards the surgeon so that by tightening the lower margin of the bag the cyst is lifted towards the surface and rolls naturally into a porringer held to receive it The moment when a hydatid rolls out of the lung intact is one of the most satisfying in surgery"

Lobectomy. The good results that follow the simpler methods for the treatment of peripherally pointing univesicular cysts will not be obtained if they are applied to the cure of cysts complicated by infection and bronchiectasis, in a series of 40 operations for hydatid disease of the lung, I have lost only one patient I was guilty of faulty judgment in attempting to treat an infected cyst of the left lung by thoracotomy and removal of the cyst The

patient had been grossly pyrexial for three weeks after a severe haemoptysis and urticarial reactions of anaphylaxis a pneumo-cyst was present on the radiograph indicating a bronchial connection and pus was mopped out of the false sac after the membranes had been removed Lobectomy should undoubtedly have been practised the patient died 48 hours after operation of a spreading septic condition of the lung in spite of full antibiotic therapy Deeply sited cysts multiple cysts extensive irreversible damage of the occupied lobe para hilar cysts and calcification are often indications for lobectomy in addition to the obvious one of associated abscess or bronchiectasis the low mortality of lobectomy

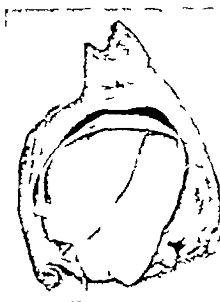


Fig *2 6—Left lower lobectomy specimen.
The lower lobe is completely atelectatic. A typical cyst wall surrounded by compressed lung tissue. (*Brit. J Surg*)

is a further factor in preferring it to other measures in the treatment of cysts which would only be doubtfully cured by simple enucleation

From time to time lobectomy for hydatid cyst will be practised when an exact pre operative diagnosis has not been made the general practice of advising exploration of all ovoid and circular tumours of the lung of doubtful nature means that a lobectomy is often preferred to direct enucleation of a mass of unknown pathology and the post operative examination of such a tumour may indicate for the first time that a cyst is present I have had this experience on three occasions

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CHAPTER 23

THORACIC INJURIES

Few thoracic injuries in civilian practice are associated with open wounds, but apart from the rare need to operate for a parietal wound the same principles that were applied in the last war control the surgical programme, namely the restoration of a normal physiology by re-adjusting altered intrapleural mechanics, the prevention of paradoxical breathing and mediastinal flutter, the clearing of air passages that have become blocked, the relief of blood loss and oxygen therapy In practical terms the measures most frequently required are the aspiration of blood and air from the pleural cavity, the application of firm pressure to the chest wall when large segments of this are " floating ", the encouragement of effective cough by the intelligent use of pain-relieving drugs and the intercostal injection of substances such as novocaine, the prompt use of tracheal or bronchoscopic suction when collapse of areas of the lung cannot be cleared by the patient's own efforts aided by postural drainage and physiotherapy is often required Only too often these measures are not employed, the illness of the patient being ascribed to such conditions as traumatic pneumonia, and too much reliance is placed on entirely passive methods of treatment

Types of chest injury

I Compression and crush injuries without obvious perforation or penetration
 (a) Without fractured ribs
 (b) With fractured ribs or sternum
II Penetrating and perforating wounds of the chest

COMPRESSION AND CRUSH INJURIES WITHOUT FRACTURE OF THE RIBS

Severe visceral damage may follow compression injuries of the chest without any obvious loss of continuity of the chest wall This group of injuries is seen most commonly as the result of high-explosive bombs and shells and accounts for many immediate deaths on the battlefield or in air raids (" blast lungs "), serious pulmonary lesions due to a sudden rise in intrapulmonary pressure are occasionally seen after motor-car accidents, sudden strains and rarely during parturition or in the severe bouts of coughing seen in whooping cough Whatever the agent, the sudden contraction or compression of the thorax associated with a shortening of the diaphragm and a tightening of the accessory muscles of respiration, including the abdominal musculature against the closed glottis, may lead to the rupture of alveoli and the tearing of adhesions pneumothorax, haemo-pneumothorax and interstitial emphysema may follow (see Fig 21 12) In exceptional conditions a main bronchus and large blood vessels may be torn, after this freak accident the patient may survive and the resultant atelectasis provides a puzzling clinical problem Such a rupture has been diagnosed and treated successfully by direct end-to-end bronchial anastomosis (Griffiths, 1949, Scannell, 1951) More usually pneumonectomy has been the only treatment possible

The management of traumatic pneumothorax or haemo pneumothorax is the same for these complications as when they follow perforating or penetrating wounds (p 526) Special consideration however is needed of the states of 'blast lung' and interstitial emphysema and crush injuries of the heart and pericardium

Blast lung

The high pressure generated by an exploding bomb or shell may have a tremendous effect upon the casualty even if no open wound is inflicted according to the weight and size of the shell or bomb blast injuries may kill or severely damage someone standing from ten to three hundred feet away from the explosion The blast effect is produced by the positive pressure exerted as a blow on the body if this force strikes the chest when the glottis is closed the sudden rise of intrapulmonary pressure may rupture large vessels but more usually tears alveoli At the same time the ribs are driven inwards and indent the lung parenchyma with consequent bruising In subjects who are not killed outright the severe lung damage is followed by a traumatic oedema which grossly interferes with the normal exchange of gases and anoxia rapidly develops Complications such as pneumothorax or atelectasis (the result of bronchial obstruction) were noted in the last war In the early stages of treatment absolute rest with the administration of oxygen is essential Ineffective cough should be assisted by trans nasal suction after local anaesthetization of the pharynx and larynx associated tension pneumothorax calls for immediate decompression (see Fig 23 4)

Mediastinal emphysema (interstitial emphysema)

Surgical emphysema is common after thoracic wounds and intrathoracic operations air escaping through a pleural tear into the muscular and fascial planes reaching in extreme cases up to the face and down to the genitalia the crepitations so easily felt by the patient and by palpation are a commonplace of thoracic surgery and though capable of causing extreme discomfort are rarely dangerous and rapidly re-absorb their treatment is primarily that of the thoracic lesion that has allowed the escape of gases into the tissues

Mediastinal or interstitial emphysema may follow a rupture of alveoli a bronchus or the oesophagus air escapes along the planes of the loose tissue that invest the bronchi and mediastinal structures to distend the mediastinal spaces from here it spreads into the retroperitoneal tissue and up into the neck where it appears as a crepitant swelling in the suprasternal notch (Fig 23 1)

Pneumothorax has long been recognized as a rare complication in new born infants after a difficult delivery in children with severe whooping cough and after antero-posterior crush injuries of the chest it is a possible complication of the rare spontaneous rupture of the oesophagus The escape of the air along the routes indicated provides a natural decompression and if the pre-disposing cause in itself is not fatal subsidence is the rule rarely however the pressure in the mediastinum may be so great that the large veins in the space are compressed and the venous return to the heart is grossly interfered with and asphyxia results In the presence of such a small incision under local anaesthesia should be made in the suprasternal notch with wide division of the loose areolar tissue and the wound left open under a simple gauze dressing protection to allow air to escape Few thoracic surgeons have ever had to perform this operation the treatment of mediastinal emphysema as of surgical emphysema involves also the correction if possible of the intrathoracic cause of the escape of air

Cardiac contusion

Perhaps the only cause of note is violent compression of the thoracic cage as in car injuries in which the steering wheel is driven against the sternum, but even this severe injury is unlikely to cause damage confined to the heart Sudden death in such happenings



Fig 23 1 —Mediastinal emphysema
(By courtesy of Mr A Aldis, The Royal Infirmary, Cardiff)

may well be due to severe anoxia, the result of concomitant lung injuries Following cardiac contusions, however, signs of myocardial insufficiency may follow with characteristic electro-cardiographic changes, this will be more likely in patients with arterio-sclerosis or pre-existent myocardial damage Suspected or proved cases of cardiac trauma should be treated as if there had been an attack of coronary thrombosis

Cardiac injuries are discussed further in Chapter 13

COMPRESSION AND CRUSH INJURIES WITH FRACTURE OF THE RIBS AND STERNUM

Apart from the wounds of warfare these are usually associated with an intact overlying skin and rarely break inwards to produce laceration of the lungs; haemoptysis or pneumothorax are more often due to the effects of lung contusion or a sudden rise in intrapulmonary pressure as the result of the compression force, haemothorax is a commoner complication than either of the above-mentioned complications Its presence may not be obvious until a few days after the injury and if undetected and untreated permanent crippling of lung and chest wall function may result

Fracture of the ribs

Most fractures are the result of anteroposterior compression injuries when this is so the ribs fracture most readily in the line of the axilla the rib breaking outwards but frequently the rib may give way more posteriorly just in front of the angle of the ribs Several ribs may be fractured in two places to leave a segment of the chest wall loose or floating with the consequence that the breathing will become paradoxical

Treatment The traditional course of ' strapping simple fractures of the ribs may not be the best method it is certainly to be used if a large segment of the chest wall is floating and associated with paradoxical breathing but in less severe degrees of fracture the pain is better relieved by a posterior intercostal injection of an oily solution of procaine The pain from a fracture of a single rib is certainly no greater than produced daily in the operation of thoracotomy with deliberate section of a rib Tight strapping in itself is a cause of considerable discomfort If the pain of a fractured rib is severe the best treatment is to confine the patient to bed for a few days together with the use of the intercostal injection mentioned and after four or five days gentle breathing exercises under the guidance of a physiotherapist should be started Intravenous procaine may be of value in relieving pain

Fracture of the sternum

The usual fracture is an incomplete one without displacement and there is no loss of the stability of the chest wall Bed rest will relieve the pain but occasionally in elderly subjects the lower lobes of the lung may collapse because the patient cannot expectorate bronchial secretions Intratracheal suction or bronchoscopy may be required and the pain should be relieved by the local injection of procaine in oily suspension into the site of fracture

If the sternum is completely fractured and the chest wall is unstable with obvious effects on the breathing mechanism the two segments should be elevated into position and fixed by silver wiring

PENETRATING AND PERFORATING WOUNDS

A penetrating wound of the chest implies a solitary entrance wound with lodgment of the missile deep to the plane of the ribs a perforating wound is usually associated with a wound of entry and exit except in the case of stab or bayonet wounds If the pleural or pericardial cavities or the mediastinum have not been involved the problems are those of a wound anywhere in the body The significance of these wounds depends entirely on the structures injured and the development of a haemothorax or haemo-pericardium If the lung is wounded in an area free of large vessels the bleeding is usually rapidly self arrested because of the low pulmonary arterial pressure and the salutary effects of lung collapse a haemothorax that develops in a patient who survives the initial trauma is usually due to bleeding from a vessel in the systemic circulation such as an intercostal artery Ten per cent of battlefield casualties who survive to reach a medical centre have thoracic wounds and the chief complication seen is haemo pneumothorax the treatment of this represents the chief surgical duty after immediate physiological derangements have been corrected

Some physiological considerations Thoracic injuries severe enough to threaten life cause the same physiological disorders whether in civilian or military practice the

lessons of warfare tend to be forgotten in peace-time but no implied differences should allow us to minimize the force of Churchill's (1944) statement that two main aims control the whole of our treatment, the first object is to save life by the immediate correction of disordered physiological states, and the second is to obtain rapid return of function and to prevent or correct sepsis

The disordered physiology Anoxia is the cause of death in chest injuries or wounds and may be due to haemorrhage or severe mechanical effects in cardio-respiratory physiology, which interfere with adequate lung ventilation and venous return Even with an intact pleural cavity the ventilation and gaseous exchange of the lungs may be grossly interfered with, as in multiple rib fractures when a large segment of the chest wall is mobile and unstable Such a "floating" area may produce effects as severe as an open pneumothorax because of paradoxical breathing with inspiration the loose segment is sucked into the



FIG 23 2



FIG 23 3

FIG 23 2 —Penetrating wound of right chest with small retained foreign body in upper lobe Traumatic pneumothorax and atelectasis of right middle and lower lobe Adhesions are holding up the upper lobe

FIG 23 3 —Areas of atelectasis due to blood in the bronchial tree after a perforating gun shot wound of the left chest
The right middle and lower lobe of the wounded side have collapsed as the result of inhalation of blood from the left side

thoracic cavity while the opposite side expands and during expiration it is pushed out, a minor degree of this paradoxical movement is seen after extensive thoracoplastic rib resections Its chief pathological effect is to allow some to-and-fro movement of gases from one lung to the other, and it is obvious that carbon dioxide will not be eliminated adequately The carbon dioxide tension in the blood will rise and the central stimulation of the respiratory centre accentuates the depth of breathing and so aggravates the paradoxical breathing, the decrease in oxygen tension in the alveolar air will quickly lead to cyanosis with all its ill effects The efficiency of the cardio-respiratory function is also hampered by the development of exaggerated displacement of the mediastinum from side to side with each inspiration and expiration The interruption of this paradoxical movement by applying firm pressure over the floating area of the chest wall, though still failing to provide normal respiratory function on the damaged side, stops the to-and-fro movement of gases from one lung to the other and at once corrects a major cause of anoxia

The open sucking pneumothorax Although a simple pneumothorax greatly diminishes the function of the lung on that side it does not interfere with the gaseous exchange of the other lung and dyspnoea is not the rule the open pneumothorax is quite different Because air can be sucked in and expelled from the wound the loss of the sub atmospheric pressure in the pleura leads to collapse of the lung on that side and to its gradual loss of ventilatory function The serious effect of the open pneumothorax depends upon the exchange of air from one side to the other across the tracheal bifurcation air from the sound lung can pass just as readily into the bronchus of the collapsed lung on the injured side as it can through the glottis since both the upper air passages and the chest wall opening are under the same degree of atmospheric pressure and paradoxical breathing results with the exchange of air steadily rising in carbon dioxide content from the sound to the collapsed lung Under this burden the respiratory exchange of the good lung deteriorates in the presence of a rising tide of carbon dioxide and a deficiency in oxygen As dyspnoea increases the pendulum movement of the mediastinum moves more violently from side to side obstructing the venous return to the heart and so leading to a fall in cardiac output The conversion of the open pneumothorax by closure of the wound by suture or by an efficient pad at once converts it into a simple pneumothorax and abolishes the pendulum movement of air from one lung to the other with an immediate improvement in the physiological state

Other factors Respiratory exchange will be further embarrassed if the tracheo bronchial passages become obstructed by mucous secretion or blood especially if pain is so severe that the cough mechanism becomes ineffective Collapse of the whole lung or of a lobe may follow (Fig 23 2) bleeding into the bronchus may produce areas of collapse in both lungs (Fig 23 3)

Tension pneumothorax A positive pressure may develop in the pleural cavity as the result of the accumulation of air through a leak in the lung of a valvular type or as the result of the accumulation of a large haemo pneumothorax The rising tension will displace the mediastinum to the opposite side impairing the ventilation of that lung and hindering a satisfactory venous return to the heart Anoxia cyanosis and an obvious engorgement of the neck veins will develop and a pulse of low pressure will indicate the decreased cardiac output it is not a common combination though frequently diagnosed Its relief is usually prompt after paracentesis of the pleural cavity when air or fluid are withdrawn If a tension pneumothorax recurs promptly after air aspiration it is evidence of a persistent lung leak and the continuous withdrawal of air by an indwelling thoracic needle attached to rubber tubing leading to a water-sealed drainage will be required

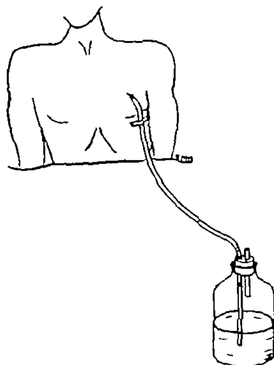


Fig 23 4 —Method used for urgent treatment of a tension pneumothorax by means of an indwelling needle connected to a water-sealed drain

Treatment of thoracic injuries or wounds

Whether the injury be a simple fracture of a single rib or a serious wound involving not only the thorax but the abdomen a routine should be followed serious sequelae may follow a simple rib fracture because an overlooked haemothorax has been allowed to

organize with severe crippling of lung and chest wall function In more severe injuries the correction of physiological disorders may be achieved successfully only to be followed by grave and often permanent complications, such as pleural or pulmonary infection, because too little attention has been paid to the full restoration of lung and chest wall function

It seems clear that the hard-won lessons of war should be applied to civilian chest trauma, though the timing of the interventions may be different because the need for evacuation of a chest casualty is not required as in war-time indeed the two phases may be merged into one with great advantage provided the full requirements of each are fulfilled Before treatment is instituted a full clinical assessment is essential

The clinical assessment Whether the injury be caused by a missile or follows a crushing or motor-car accident the first duty is to ascertain, as soon as possible, if the injury is purely thoracic or associated with lesions elsewhere such as the spine or abdomen The thoraco-abdominal wound is an obvious example, and in crush injuries serious chest damage may be complicated by renal, splenic, hepatic or other visceral ruptures rigidity of the abdomen is a common accompaniment of purely thoracic injuries and indeed was seen in most of the haemothoraces caused by gun-shot wounds of the chest during the first 24 hours A careful study of the external evidence provides information, but difficulty is experienced in warfare in assessing the probable course of a missile when the wound is of the lodging type, there being signs only of one external wound

Wounds or injuries elsewhere having been detected or excluded, the clinical examination of the chest and cardio-respiratory follows the usual lines dyspnoea and haemoptysis may be obvious indications of severe intrathoracic mischief an open sucking pneumothorax will be detected at once and immediately closed by the application of a firm sealing pad fixed as a first-aid measure by strapping The position of the apex beat of the heart and the trachea may provide evidence of mediastinal displacement due to the presence of air or blood or both in the pleural cavity paradoxical breathing in patients with the "stove-in" chest indicates the need for immediate fixation of that side by pads and firm strapping Surgical emphysema which may rapidly spread beyond the confines of the chest wall is declared by the characteristic subcutaneous crepitations that crackle under the examining hand applying light pressure

Percussion and auscultation may reveal the presence of a pneumothorax or of a collapsed lung or lobe of a lung, but both may exist without obvious auscultatory evidence and the stethoscope is not a reliable method of detecting serious intrathoracic lesions and can never rival the accuracy of radiological findings , a comparatively large haemothorax may exist with surprisingly few physical signs It is important to remember that much pleural fluid may be present without clinical evidence of mediastinal displacement Of greater value is the detection of dullness to percussion associated with absent breath sounds, but complete reliance on this valuable method of examination is not wise

Unless the patient requires urgent correction of dyspnoea, the result of a sucking open wound or of a tension pneumothorax, an immediate radiological examination is essential and should precede all operations or the aspiration of haemothorax fluid if the patient is unfit to be examined by radiography he is certainly too ill to be subjected to major surgery apart from the closure of a sucking open pneumothorax or the relief of an obvious tension pneumothorax The availability of X-ray apparatus in the Casualty Clearing Station in the last war was often of inestimable value and saved many lives the same can be said of the value of the portable X-ray machines in the wards of a civilian hospital

The first phase of treatment

The same principle, the immediate correction of disordered physiological states applies to the different classes of injuries These are penetrating and perforating wounds non penetrating wounds abdomino thoracic wounds and compression wounds of the lung or heart in this group belong the important class of ' blast injuries The chief causes of severe symptoms or of death are anoxia and blood loss the anoxia may result from the mechanical effects of paradoxical respiration from tension pneumothorax or collapse of wide areas of lung the result of bronchial obstruction from intrabronchial mucous plugs or haemorrhage

Severe haemorrhage from damage to large vessels or the heart will produce anaemic anoxia In the correction and relief of these states the closure of sucking open thoracic wounds the arrest of haemorrhage the relief of paradoxical breathing and the decom pression of a large haemo pneumothorax or a tension pneumothorax require immediate application The clearance of blocked air passages by trans nasal suction or bronchoscopic aspiration play an essential mechanical rôle while the relief of pain the replacement of severe blood loss by transfusion and the administration of oxygen by an efficient method will be at times of vital complementary assistance in restoring normal lung ventilation and an efficient cardio-vascular system These measures form the chief agents employed for the relief of the labouring cardio respiratory system and are of *greater importance* than major surgical interventions at this stage

(*a*) **Correction of open pneumothorax and of paradoxical breathing The treatment of shock** Whatever the cause an open sucking pneumothorax wound will produce increasing dyspnoea and cardio vascular distress unless closed closure is effected immediately by the use of air tight pads firmly fixed in place Suture without excision of the wound edges devitalized muscle and loose rib fragments is dangerous as such closure is attended by a high rate of infection in the thoracic wall layers and in the pleura Many penetrating and perforating wounds produced by high velocity missiles such as rifle bullets or stabbing do not in fact suck and may not require excision The real sucking wound should only be sutured after adequate wound excision.

In the wounds of warfare the greatest judgment and experience is required before a formal thoracotomy is performed during the first phase of treatment if a large sucking wound is excised it may be tempting to carry the exploration sufficiently widely to explore the whole pleural cavity this is not always advisable and the surgical endeavour should be to provide a safe closure after a rapid examination has allowed easily accessible foreign bodies in-driven fragments of rib and blood clots to be removed Lung tears however formidable they appear at this operation should not be excised and the advice that wedge-shaped resections or even lobectomies should be carried out will not commend itself to the surgeon with extensive war time experience of these conditions seen soon after wounding I know of only one lobectomy being practised for gun-shot wounds of the chest in the whole of the 1939 45 war

Lung lacerations rarely bleed severely such bleeding points are underpinned with fine catgut sutures Since gas gangrene does not occur in the lung there is no need for the excision so necessary in the case of wounds elsewhere

The chief exceptions to this attitude of cautious intervention are thoraco abdominal wounds bleeding from large vessels such as the subclavian vein and cardiac wounds that have survived the original trauma

In closing the sucking wound the pleural membrane is not amenable to direct suture and the defect is sealed by suture of the overlying muscles If the patient is to be retained

in the same hospital the skin can be closed, but if he is to be evacuated in the course of military operations the skin is left widely open, the wound being lightly packed with dry gauze Delayed primary suture can be effected safely at the centre to which he will be evacuated.

Bleeding in thoracic wounds Apart from wounds of the great vessels and heart which are often immediately fatal, most intrapleural haemorrhage comes from the chest wall injury and only in small part from the lung The low vascular pressure in the latter is usually controlled by its associated collapse towards the mediastinum, unless it is held out by adhesions, the result of previous lung inflammations · in wound excisions the intercostal vessels are frequently seen to be torn and bleeding and require ligation

The treatment of shock. The chief essentials are the relief of pain, the correction of blood loss by carefully controlled blood transfusion (excessive transfusion is dangerous), the *correction of anoxia by taking measures to keep the airways clear and providing oxygen.* The haematocrit findings are of considerable help in estimating the volume of the blood transfusion

The correction of paradoxical breathing The conversion of the open sucking pneumothorax to a closed one corrects this · in wide disruptive injuries of the thoracic cage the prevention of paradoxical movements and the associated to-and-fro passage of air from one bronchus to the other is achieved by firm padding of the loose chest wall segments This steadying of the chest wall accompanied by a careful but indicated use of morphia, the injection of an oily solution of procaine into the posterior intercostal spaces and the administration of oxygen (preferably in a tent, though an oxygen mask will have to be used in warfare) will usually relieve the dyspnoea

(*b*) **Haemothorax and haemo-pneumothorax.** The adequate, early treatment of haemothorax is the most important single duty in the treatment of chest trauma, for this is the major complication of chest injuries, military or civil In 1,000 consecutive chest wounds treated in Italy in the hospital in which I worked, 839 were complicated by a haemothorax no doubt this incidence is an unusually high one because only patients with severe or suspectedly severe wounds of the chest were referred there

The dangers of a haemothorax or a haemo-pneumothorax are undesirable mechanical effects upon the lung, chest wall and the mediastinum and the risks of their subsequent infection These can be avoided largely by early aspiration of the intrapleural fluid, for this corrects abnormal pressure effects, encourages rapid lung expansion, normal chest wall and diaphragmatic function, and removes an admirable habitat for the growth of organisms The fear, still occasionally expressed, in spite of the much-publicized experience of warfare, that early aspiration may restart haemorrhage is unfounded and contrary to hard clinical experience In the last war, the practice of aspirating a haemothorax twelve hours after wounding was widely accepted Since the bleeding is usually from the chest wall there is no danger of restarting pulmonary haemorrhage, for clotting in the pulmonary parenchyma is rapid and effective The whole aim of treatment being to obtain full and rapid lung re-expansion, the use of air replacement to maintain collapse of the lung, with the object of preventing lung bleeding, has no logical support and should not be practised

Some clinical and biological features of haemothorax In the course of days a small haemothorax may become a large effusion, quite apart from any continued bleeding into the pleura The blood itself acts as a pleural irritant, exciting the transudation of serous fluid, and even if aspiration is done twelve hours after the wound or injury the removed fluid usually has a red cell count and haemoglobin percentage below 50 per cent of the figures of normal circulating blood Blood in the pleural cavity clots at two important

stages any surgeon who has dealt with the primary phase of the treatment of gun-shot wounds of the thorax knows that bulky red jelly like clots are commonly present the more extensive the damage to the chest wall and the lung the greater is the tendency to clot formation due no doubt to the release of clotting enzymes Under the influence of chest wall and cardiac movements defibrination can and does take place the solid elements of the haemothorax fluid becoming adherent to the parietal visceral and diaphragmatic pleura infection with certain organisms usually of mild virulence may accelerate the process of intrapleural thrombosis Once the clotting process has become extensive large masses of fibrinous deposits appear and often form multiple pockets which enclose air and sero-sanguineous fluid

The clotted haemothorax is in reality a compound process in which serum blood cells and fibrin are entangled If left in place this coagulation becomes organized on to the chest wall and visceral pleura with great impediment to the movements of lung and the parietes A cortex of sero-fibrinous material readily forms and if exposed by open operation from the second to sixth week can be readily peeled off the structures it encases Such an operation was employed with great frequency in the war time clotted haemothorax but exactly the same intervention is required for the occasional casualty in civil practice If left undisturbed the peel becomes densely organized and invaded by firm blood vessels but even at a late date an area of separation can be found at operation as in the decortication operation for chronic empyema tuberculous or pyogenic

In addition to the severely deleterious effects on lung and chest wall movements the clotted haemothorax readily becomes infected and the advent of sepsis alters the clinical picture

The mechanical effects may be expressed by dyspnoea and cyanosis the displacement of the apex beat and trachea together with the typical percussion and auscultation features of a pleural effusion when present make the diagnosis obvious but these features are not always of the classical pattern and radiology is essential to disclose the estimated size of the haemothorax the effusion occasionally may be extrapleural (d Abreu Hodson and Litchfield 1944) Evidence of complicating infection is not as easily obtained as might be imagined the infected haemothorax is naturally associated with a daily pyrexia of 99 -100 and this will be exaggerated if there is an associated collapse of a lobe of the lung in which organisms multiply rapidly The bacteriological examination of aspirated fluid is not always decisive as the exploring needle may overlook pockets of infected haemo thorax fluid when a multilocular clotted effusion is present Infection however is proved when there is significant pyrexia on the microscopic and macroscopic appearances of aspirated fluid and when pathogenic organisms are revealed by direct bacteriological examination or by culture (d Abreu Litchfield and Thomson 1944) When the aspirated material from a haemothorax changes daily from clear red to turbid pink or salmon-coloured fluid infection is present

Treatment of the simple uninfected haemothorax Thorough early aspiration and the use of breathing exercises under a trained physiotherapist are the essentials the techniques employed depend largely on radiological appearances and unless postero-anterior and lateral films are available attempts to withdraw fluid may fail or be inadequate At the first aspiration local anaesthesia is preceded by a pre-operative sedative such as omnopon and hyoscine and the patient is propped up in as comfortable a position as possible to enable the operator to insert the needle at the most appropriate site after a study of the X rays as in all effusions the diaphragm on the affected side is raised and the selection of too low a site for the paracentesis is a common error and a frequent cause of failure to contact the

fluid Much of the air and haemothorax fluid is withdrawn as the aim is to secure early lung re-expansion air replacement is never practised as a routine though the occasional introduction of a little may be required if the patient becomes dyspnoeic at the close of the performance A little air may be let in to enable post-aspiration radiographs to demonstrate loculations that may be present At the end of the aspiration 200,000 units of penicillin are left intrapleurally if subsequent bacteriological examination shows that there are no penicillin-sensitive organisms present, this may be omitted after three withdrawals or replaced by a more suitable antibiotic if the organisms are resistant The paracentesis should be repeated on alternate days until only a little serous fluid remains and the radiograph shows a satisfactory pleural state with lung re-expansion

Thoraco-abdominal wounds The reliance placed on a judicially conservative management of most thoracic wounds in which physiological derangements can be corrected by relatively minor surgical measures cannot be justified in the more serious thoraco-abdominal wounds If an abdominal viscus (apart from the liver) has been injured, its prompt care by aggressive surgery is essential and governed by the principles that guide the management of abdominal wounds Intra-abdominal bleeding and peritonitis are far more lethal complications than those associated with haemothorax or pleural infection The mortality rate of thoraco-abdominal wounds varies between 20 to 50 per cent (Betts, 1946, Blackburn and d'Abreu, 1945) It is important to remember that if the wound of entry is in the thorax (thoraco-abdominal) the prognosis is better than if the wound is in the reverse direction (abdomino-thoracic), because in the latter, hollow viscera are more frequently damaged and this plays an important rôle in governing the mortality rate

Pre-operative estimation of the patient A full physical examination of the chest and abdomen may confirm the estimated path of the missile, this latter point is easily judged if there is an entry and exit wound but obvious difficulty presents in the instance of a penetrating, lodging wound The physical signs of a peritoneal wound include abdominal pain, rigidity, tenderness, absence of peristaltic sounds and occasionally absent liver dullness, considerable difficulty is experienced if the upper abdomen on the side of the wound is the only site of rigidity, as this may be caused entirely by the thoracic wound

If reasonable doubt is entertained as to the presence or absence of an abdominal visceral wound, exploration is advisable and should be carried out as soon as the cardio-respiratory derangements have been corrected by first-aid measures already described

The choice of incision for the abdominal exploration If an adequate operation can be performed through one incision, such an approach carries enormous advantages over two separate ones, there can be no doubt that the mortality rate in the last war when the abdomen and thorax were explored through two separate incisions was extremely high A purely abdominal approach is justified if the chest lesion is insignificant and the problem of pre-operative assessment is essentially an abdominal one requiring no operation on the chest It should be stated at once that the combined thoraco-laparotomy approach with division of the diaphragm gives poor access to the lower abdomen In the typical thoraco-abdominal wound the abdominal viscera damaged are usually the spleen, liver, stomach, kidney and the colon, especially in the splenic flexure area All of these wounds can be adequately dealt with by thoraco-laparotomy

The outstanding advantages of the thoracic approach are

(1) repair of the diaphragmatic wound is simple and free from the severe difficulties of closure through an abdominal approach, if the diaphragm is not closed the post-operative incidence of chest complications is raised and later complications from a diaphragmatic hernia are not uncommon,

(2) the repair of lesions of the upper half of the stomach and exteriorization of a damaged splenic flexure of the colon are easier through this route than by laparotomy alone

(3) splenectomy through a trans-diaphragmatic approach is a simple procedure

(4) with good anaesthesia the patient can be maintained in a lighter plane of anaesthesia as relaxation is more easily obtained

(5) the pleural cavity can be cleared completely of clot missiles or fragments of clothing thus greatly diminishing the post-operative risk of pleural and pulmonary complications In patients treated entirely by an abdominal incision the incidence of thoracic complications was higher than in those subjected to a combined thoraco laparotomy approach this was especially so when intestinal or gastric contents had soiled the pleural cavity

Finally the thoracic approach enables a correct excision of the chest wall wound to be done and this greatly decreases the empyema incidence

As the late war progressed increasing confidence was placed in thoraco laparotomy the advances in the use of this incision for such operations as oesophagectomy total gastrectomy and splenectomy since the war have only heightened the indications for this approach in this type of wound but failures will follow if the full post-operative regime fails to take care of such post-operative complications as haemothorax and atelectasis in addition to the accepted rules of management of the abdominal state by measures such as intragastric suction and adequate fluid and electrolyte replacement

The second phase of treatment

Once the dangers to life from disordered thoracic physiology have been corrected by the measures discussed attention must be paid constantly to the prevention and treatment of sepsis and the rehabilitation of lung function Basically both these aims are largely achieved when the lung is fully expanded and in contact with a well healed intact chest wall The chief hindrance to this happy result is the development of an empyema the clotting and organization of a haemothorax and the collapse of the lung or one or more lobes Fortunately by correct handling of the haemothorax the use of antibiotic therapy and of physiotherapeutic measures combined when needed with bronchoscopic or trans nasal suction of intrabronchial plugs of muco pus, these complications are readily avoided In some patients however a haemothorax will clot become infected and shut off into pockets that resist all attempts at aspiration * From experience in the last war in all theatres it is clear that such complicated haemothoraces should be treated by major thoracotomy removal of the products of the haemothorax and decortication of the organized exudate and blood clot on the pleural surfaces The same approach should be employed in the problem of post traumatic empyema the aim being to obtain immediate and complete re-expansion of the lung with the avoidance of persistent and discouraging tube drainage of the empyema

Treatment of the clotted and infected haemothorax

If the criteria of infection already mentioned develop or a pleural haematoma is present determined aspiration with appropriate intrapleural and parenteral antibiotic therapy may cure some but major surgical interventions will be indicated when the haemothorax is clotted loculated or infected and when the amount of intrapleural fluid does not decrease rapidly after aspiration therapy If aspiration methods are employed for too long the lung

* Samson and Burford (1947) who did so much in the last war to establish the operation of decortication found that 10 per cent of patients with battle incurred haemothorax showed evidence of extensive clotting and that such a complication led to infection far more frequently than in unclotted effusions

fails to re-expand as it lies imprisoned beneath its sero-fibrinous envelope and the chest wall movements steadily decrease The dangers of a chronic empyema and of a " frozen " lung and chest wall can only be overcome safely by thoracotomy, clot removal and decortication of the lung and parietal pleura including the diaphragmatic surface The safety of this method and its excellent results were established beyond doubt in the last war, the chronic disabling empyema so often seen in the Ministry of Pensions Hospital for years after the 1914–18 war is today quite exceptional

The operation The principles are the same whether obvious infection is present or not and the application of this war-time operation to the cure of empyema of non-traumatic origin has been discussed in Chapter 6

A wide thoracotomy is necessary and the sixth or seventh rib may be excised or an intercostal incision with division of one or more rib back ends is excellent : the lung must be freed sufficiently in any adherent areas before the rib spreaders are placed and opened. All fluid and fibrin and blood clots are thoroughly removed from the pleural space and this entails the deliberate breaking down of any loculated pockets, infected or uninfected. The lung will be seen encased in its coat of imprisoning exudate beneath which will be a normal shiny bluish pleural membrane. The immobility of the lung and the obliteration of the normal fissures will be obvious The enclosing membrane is carefully incised down to the normal pleura : in cases older than four to six weeks the fibro-elastic membrane so well described by Samson and Burford will be laminated and some difficulty may be experienced in seeking out the true layer of dissection, which lies immediately over the pleural membrane to which it is connected by tiny blood vessels if organization has proceeded to that stage

Once the membrane has been incised sufficiently, in several directions if need be, it can be grasped in forceps and peeled off the lung by a mixture of finger, swab and scissor or knife dissection If the lung is penetrated slightly air will bubble out, this is not serious and usually stops after the application of a moist swab, though occasionally very fine sutures may be required for the larger tears in the area of any lung wound the fibrotic membrane should be left intact after a circular incision has been made around it. The whole lung must be mobilized thoroughly and the fissures completely defined It is an advantage to remove the peel as thoroughly as possible off the diaphragm and parietal pleura

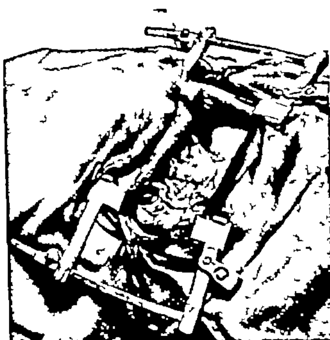
Throughout the operation the anaesthetist should gently distend the lung, as this facilitates the decortication and enables an estimate to be made of the thoroughness of the release obtained

At the end of the operation the chest is closed, drainage being provided by one or more intercostal catheters to which gentle motor suction is applied (Price Thomas and Cleland 1945) In most instances the lung is fully re-expanded in 48 hours and the tubes are removed any subsequent effusions are treated by aspiration Active breathing exercises are commenced immediately

If any doubt exists as to the value and the excellent results of this operation reference should be made to a large range of papers on this subject, the work of Samson and Burford (1947), Nicholson (1946), and Price Thomas and Cleland (1945) is of great interest and value

The surgery of retained missiles

The presence of a foreign body within the thorax is undesirable here as elsewhere and as a general rule fragments over 1 cm in size should be removed whenever possible This may be a counsel of perfection, but since the operative risk in most instances is extremely



(a)



(b)



(c)

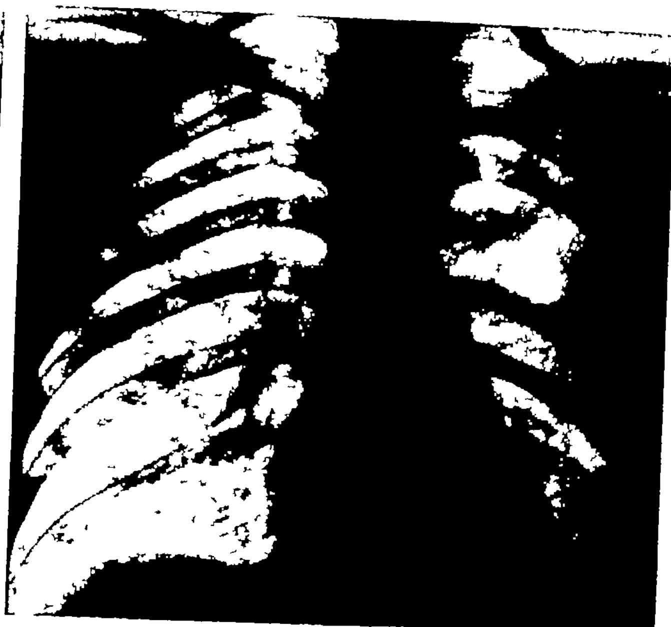
Fig 23 5

(a) Thoracotomy for infected partly clotted and organized haemothorax
(b) After the decortication
(c) The wound after closure and the provision of under water sealed temporary drainage

(By courtesy of Lt.-Col Frank Nicholson, R.A.M.C.)



(a)



(b)

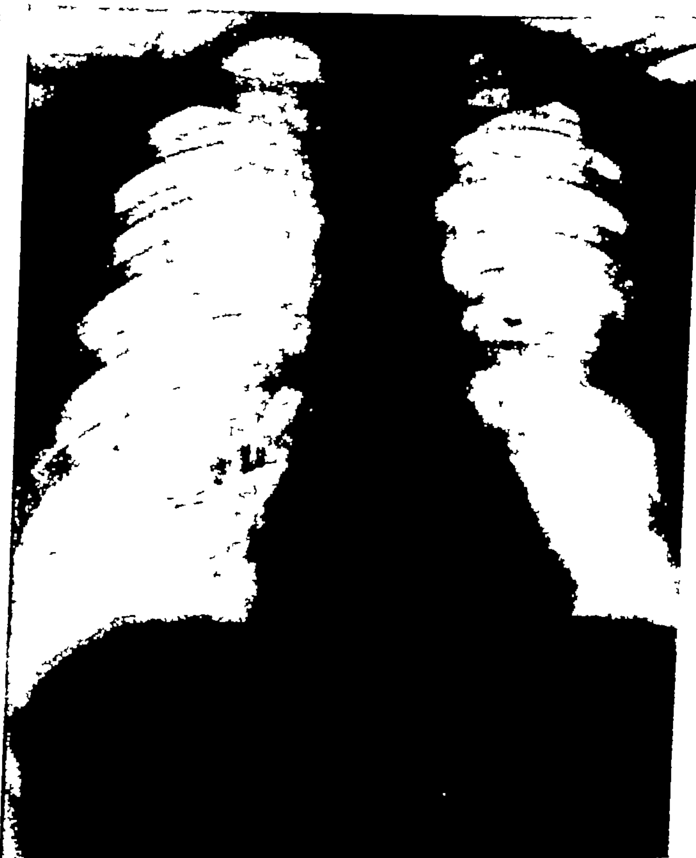
FIG 23 6

(a) Radiograph of chest after penetrating gun shot wound
The left lung is completely collapsed and held down by an organized haemothorax

(b) The same patient three weeks later after thoracotomy and decortication
(By courtesy of Lt-Col Frank Nicholson R A M C)



(a)

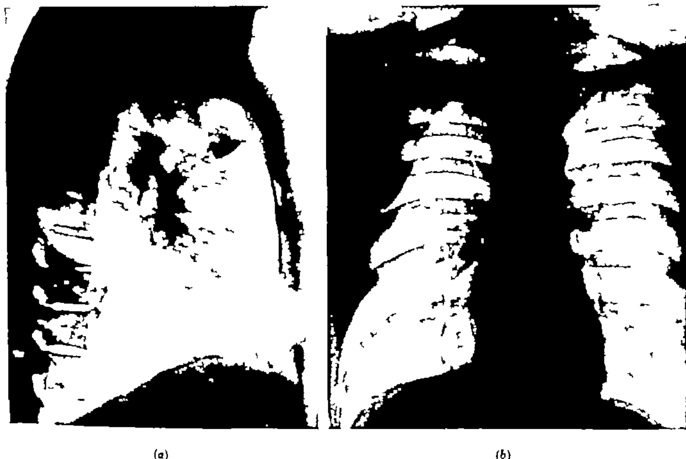


(b)

FIG 23 7

(a) Gun-shot wound of left chest showing a typical clotted multilocular haemo pneumothorax
(b) The same patient three weeks after thoracotomy and decortication

low and the late complication rate high removal was frequently carried out in the late war Even in the early stages severe complications may be seen in a series of 206 cases of retained intrathoracic missiles some severe complications were noted in the first six weeks as follows 2 deaths from haemoptysis 10 empyemata associated with peripherally sited lung missiles 10 small abscess cavities around intrapulmonary fragments and 12 empyemata associated with pleural missiles In the same series several recurrent pericardial effusions and mediastinal abscesses were due to retained missiles The late complications may be traumatic lung abscess bronchiectasis or empyema (Fig 23 8)



(a) (b)

Fig 23 8

(a) Bullet in right upper lobe

Wound inflicted six years previously repeated small haemoptyses for a month before this radiograph was taken. There is a small abscess cavity around the bullet which was removed and the abscess cavity was obliterated by suture with relief of all symptoms

(b) Bullet in right upper lobe

A track can be seen leading to the bullet.

(By courtesy of Lieut Col Frank Nicholson, R.A.M.C.)

The removal of foreign bodies from the lung and pleura presents no technical difficulties if the pre-operative localization has been exact with reference to fissures and lobes being far more important than the study of bony localizations since these are of little value once the pleural cavity is widely opened. The foreign bodies in the lung are easily palpated unless surrounded by haematoma formation in such instances localization is usually possible by the use of a needle and by radiological screening in the theatre The missile track in the lung is often palpable because of the solid core of effused blood such tracks are often identifiable on the pre-operative radiograph (Fig 23 8 (b))

The outstanding contribution of Harken (1947) to the surgery of retained missiles in or near the heart has been referred to in Chapter 13

Lung Abscess

Lung contusions were seen frequently in the last war They represented areas of effused blood and of oedema fluid, they rarely broke down into abscess cavities and those that did almost invariably responded to antibiotic therapy Abscess cavities, usually without the features of real lung abscess, were sometimes seen around retained lung foreign bodies, being more noticeable if the fragment concerned was a portion of in-driven rib The treatment of such abscesses was removal of the foreign body, obliteration of the space by suture and antibiotic therapy They had none of the malignity of true lung abscess In 1,000 war wounds of the chest, 32 lung abscesses were seen, 13 around lodged foreign bodies and 19 without retained missiles

Pleurobiliary fistula and chylothorax

Thoracic wounds or trauma may be followed by the presence in one or both pleural cavities of bile or chyle, the former being by far the commoner

Bilothorax. In over 1,000 consecutive thoracic wounds seen at a Base Hospital, seven had bile in the right pleural cavity following thoraco-abdominal wounds that had involved the liver . in all instances the diagnosis was unsuspected until the chest was aspirated for a supposed haemothorax In spite of careful aspiration and penicillin therapy all these patients developed empyema which required drainage This is of some interest in view of the short-lived fashion many years ago of attempting to sterilize empyemata by the injection of bile salts these seven patients all recovered uneventfully

Chylothorax. In a considerable war experience I only saw one traumatic chylothorax . this followed a bayonet wound of the lower thorax Surprisingly chyle was found in both pleural cavities and accumulated so rapidly that bilateral intercostal drainage was employed The patient died of inanition rapidly ; at autopsy the thoracic duct was seen to be severed Undoubtedly thoracotomy should have been practised in this patient, who had, however, other wounds and was critically ill on admission

Etiology of chylothorax About half of the reported instances of chylothorax have been attributed to injury, the result of direct or indirect violence of which the most important seem to be violent hyperextension of the spine, the other half complicates malignant disease which involves the posterior mediastinum or the retro-peritoneal area, most usually in the shape of glandular compression or lymphomatosis or secondary carcinoma Since 50 per cent of patients with chylothorax die from inanition (Meade *et al*, 1950) surgical relief by tying off the thoracic duct should always be considered

The thoracic duct may be damaged in the thorax by injury or surgical operations, or torn as the result of injuries involving violent movements of the spine Injury to the thoracic duct in the neck has provided many examples and ligation has usually been successful In thoracic surgical operations the duct, or branches of it, may be damaged especially during the course of an extra-fascial apicolysis combined with upper thoracoplasty for tuberculous cavities A large amount of chyle pours into the wound when this happens the wound should be re-opened and the duct ligated, usually the second stage of the thoracoplasty can be executed at the same time In the writer's knowledge this has been done on four occasions, one in his own practice

It is strange that damage to the thoracic duct and its tributaries does not often complicate such radical operations as oesophagectomy, it is a rare complication of trans-thoracic thoraco-lumbar sympathectomy for hypertension Twice in the course of Blalock's operation for subclavian-pulmonary artery anastomosis I have seen chyle exude from a

lymphatic duct after the left subclavian artery had been mobilized but no complication followed the immediate ligation of these channels

Clinical features of chylothorax With rupture of small tributaries of the duct symptoms may be slight the diagnosis being made unexpectedly after aspiration for a suspected pleural effusion occasionally a diagnosis of chylothorax may be made on the macroscopic appearances only of milky white fluid when the case in fact is one of pseudo-chylous effusion due to chronic inflammation In such patients the fat content of the fluid is low Nor does the administration of Sudan III lead to its recovery in the urine as occurs in true chylothorax with chyluria (Fletcher 1930)

In more serious lesions the continuous loss of chyle with its fluid protein and fat content may lead to dehydration and starvation The presence of chyle though apparently not leading to infection causes a gross pleural reaction which becomes greatly thickened and covered by an exudate which leads to loss of chest wall and lung function The lymphocytes and eosinophils in the blood showed a notable fall

Treatment This has been well described by Meade and others (1950) The first attempt at treatment should be by aspiration as half of the recorded cases have been arrested by this measure If aspiration fails to decrease the daily escape of chylous fluid into the chest closed drainage should be employed with the aim of producing rapid lung re-expansion If this second method fails surgical exploration is essential and should not be delayed for more than one to two weeks At thoracotomy the leak may be difficult to find when damaged the duct should be ligated above and below the area of leak

The metabolic derangements caused by the chylous loss is best met by a high protein and fat diet the intravenous re infusion of aspirated or drained chyle may be dangerous because of the risks of anaphylaxis

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PART VII

THORACO ABDOMINAL SURGERY

INTRODUCTION

Fortunately or unfortunately no statutory body has attempted to define the scope of thoracic surgery one cynic has said that the field extends from the third thoracic to the third lumbar vertebra! If this be true it would be better to speak of regional surgery rather than the surgery of systems and it would be quite as illogical to restrict the thyroid or abdominal surgeon to the reaches of the neck or abdomen as to forbid the thoracic or abdominal surgeon to proceed beyond the outlet or inlet of the thorax In practice if a surgeon has mastered the main details of abdominal surgery is proficient in the endoscopic examination of the gullet and tracheo bronchial tree and is capable of managing both abdominal and thoracic complications such as paralytic ileus electrolyte and fluid imbalance or collapse of a lobe of the lung pleural effusion or empyema he tackles the problems of thoraco-abdominal surgery The major complications of this branch of surgery are often thoracic and perhaps for this reason much of this surgery finds its way to thoracic clinics it is exacting work that demands a great deal of concentration and is time-consuming to a degree Adequate pre-operative and post-operative measures influence the results more perhaps than in any other branch of surgery

The diaphragm is no longer a barrier to the abdominal or thoracic surgeon its easy exposure section and repair present no technical difficulties and access to the infra-diaphragmatic compartments need not be inadequate The exposure of the cardia the upper half of the stomach and the spleen by a purely abdominal approach is often unsatisfactory hazardous and cramped and although lesions of these areas can be dealt with by upper laparotomy there is no need for poor exposures when the condition demands a clear demonstration. If thoraco laparotomy is used post-operative attention must be divided equally between the care of the abdomen and the thorax Thoracic complications are avoidable if the normal physiology is restored at the end of the operation in practice this is achieved by effecting complete lung re-expansion as early as possible fortunately the factors that impede this namely pneumothorax atelectasis and pleural effusion, are detectable and correctable This will require constant radiological control commencing preferably in the operating theatre at the end of the operation so that the patient returns to the ward with the lung fully re-expanded and aerated often encouraged by bronchoscopy and aspiration of air from the pleural cavity A radiograph taken in the ward on the first post-operative day is essential whatever the physical signs and clinical condition of the patient on this radiological information adjustment of any drainage tube used aspiration of air or fluid or bronchoscopic suction for atelectasis can be conducted In the absence of readily available radiological facilities thoraco-laparotomy is dangerous and ill advised The maintenance of the patient in correct fluid and electrolyte balance will prevent many of the abdominal metabolic and cardio-respiratory complications

Some indications for thoraco-laparotomy

A consideration of the war-time approach to wounds of the left chest and the upper left quadrant of the abdomen showed the benefits of thoraco-laparotomy wounds of the lung, diaphragm spleen, stomach and splenic flexure of the colon were more adequately dealt with by a single combined incision than by a purely abdominal or thoracic approach, and such an exposure has completely ousted the use of two separate incisions If adequate exposure is needed there can be no objection to a transpleural approach now that adequate anaesthesia and thoughtful post-operative chest care are available

In civilian surgery, certain lesions can only be approached with any degree of satisfaction by thoraco-laparotomy and typical of this group is cancer of the cardio-oesophageal junction, which can be dealt with radically only by this combined route For ease of approach thoraco-laparotomy is preferable in many instances for splenectomy, adrenalectomy carcinoma of the stomach, a few types of highly placed gastric ulcer, especially when these are sited in a thoracically placed loculus of stomach, the performance of an anastomosis between the portal vein and the inferior vena cava in the treatment of portal hypertension and for diaphragmatic hernia In many of these exposures the approach need only be transpleural and trans-diaphragmatic without the full extension of the incision across the upper abdominal musculature, and the costal cartilage framework

CHAPTER 24

SURGERY OF CARDIO OESOPHAGEAL OBSTRUCTION AND THE UPPER THIRD OF THE STOMACH

Confronted with the problem of lower dysphagia the surgeon must keep an open mind on the suggested pathological basis of the lesion until radiological oesophagoscopic and histological evidence is available as a check on clinical impressions However tempting it may be to regard a patient s history and symptoms as typically those of cardiospasm this diagnosis may be dangerous even when radiological appearances seem typical until an oesophagoscopic examination has been performed It is easy to demonstrate radio graphs apparently typical of cardiospasm in which oesophagoscopy has revealed a carcinoma of the oesophagus above or below a typical area of achalasia spasm

Of patients with gastro-oesophageal obstruction about 60 per cent have carcinoma 25 per cent peptic ulceration and 15 per cent cardiospasm In my experience in adults the most prolonged history of dysphagia has been in the peptic ulceration group shortest in the carcinoma series and intermediate in the cardiospasm although the longest individual history in a few patients has been in the last mentioned group one having had dysphagia for over thirty years Except for the surgical treatment of cardiospasm (as apart from efficient dilatation—see p 442) which is preferably dealt with through a purely thoracic approach a thoraco laparotomy approach is often needed for the attempted cure or palliation of carcinoma of the cardia and for advanced peptic ulceration of the oesophagus when oeso phago-jejunostomy has been selected as the best treatment For the repair of hiatus hernia by Allison s method the approach is thoracic but is supplemented by a small incision made through the diaphragm as described later Carcinoma of the stomach even when not producing dysphagia is best dealt with through a thoraco abdominal approach if radical total gastrectomy has been chosen

The thoraco-laparotomy incision

Although not confined to the left side this approach is the one applied most commonly a modified right sided one being employed for the operation of porto-caval anastomosis for the relief of portal hypertension (Satinsky 1950) or the exposure of the right suprarenal gland

The choice between opening the abdomen or thorax first is not academic but depends on pre-operative decisions if a palliative or radical gastrectomy is being undertaken for a gastric cancer without dysphagia the abdomen is opened first for evidence of opera bility or non-operability through this incision the liver glands and peritoneal spaces are searched for metastases that may proclaim inoperability once resection has been decided upon the abdominal incision is continued along the line of the eighth or seventh rib to provide a full abdomino thoracic approach If however the aim is to correct dysphagia in a one-stage operation as advised by Allison (1940) the full thoraco-laparotomy approach is employed from the start if the condition found is amenable to resection the radical operation is commenced if the growth is irremovable palliation of the dysphagia by an oesophago jejunostomy is best performed through the full incision

Pre-operative measures and anaesthesia Many of these patients are elderly emaciated

and toxic and ample time is needed for pre-operative measures in hospital. The first step is often to restrict solids by mouth even if swallowing them is possible; a fluid diet will provide calories and vitamins more readily than unhappy attempts at forcing solids, a considerable variety of flavours can be used and commonly a gain in weight is achieved. After each fluid meal the oesophagus must be washed through with water drinks if there is partial cardio-oesophageal obstruction.

Oral hygiene for dental sepsis may involve dental extractions and the removal of tartar; frequent mouth washes and the sucking of penicillin lozenges are used. If teeth have to be extracted the operation should be delayed until the gums are healthy and clean.

The anaemia and disturbance of the plasma proteins consequent on the effects of dysphagia (accentuated by the changes that follow a carcinoma of the stomach if this is the site of the growth) are best corrected by blood transfusions in the pre-operative period. Plasma may be selected in spite of the risks of serum jaundice, but intravenous amino acids have been of disappointing value. Pre-operative chest exercises are used with caution and not pressed vigorously until the other pre-operative measures have produced a reasonable improvement. Iron is given by mouth in addition to the administration of vitamins; the need for extra vitamins is clear because the storage of these in the tissues has been greatly depleted as the result of deficient intake or failure to be absorbed in patients with gastric carcinoma; their need in the post-operative phase of healing is too well known to require further mention. If the patient is in negative water and electrolyte balance, usually the result of vomiting, or gastric aspiration, the administration of appropriate intravenous solutions is essential. Systemic penicillin (half a million units twice a day) is started two days before operation.

Anaesthesia. Allison (1949) has advised certain measures to prevent post-operative complications, the chief being the prevention of oesophageal contents spilling into the tracheo-bronchial tree during the induction and maintenance of anaesthesia, and when the patient's position is being altered at the end of the operation. Under pentothal and curare the oesophagoscope is passed and the contents of the gullet are aspirated. A tampon is placed below the crico-pharyngeus muscle to avoid all risk of upward spill. After the pharynx and nose have been aspirated carefully a pharyngeal airway is introduced and carefully packed off. Anaesthesia is maintained by pentothal, curare and oxygen with occasional assistance from anaesthetic agents delivered through a perfectly fitting face-mask, so that the lung can be inflated as much as desired during the operation. The need for an intratracheal tube, which may damage the mucosa and lead to tracheal infection during a long operation, is dispensed with if the vocal cords are relaxed by the use of curare. Many surgeons, however, use such a tube.

Anaesthesia may be supplemented and haemostasis improved by blocking the lower intercostal nerves and the line of the thoraco-abdominal incision with local procaine solutions to which amethocaine and adrenaline have been added. Throughout the long operation the anaesthetist must prevent atelectasis of any area of the exposed lung as this adds to the burdens of the patient during and after the operation. While the oesophagus is being dissected in the mediastinum the inflated lung can be held away by an assistant to provide satisfactory exposure.

At the close of the operation and before the patient is turned from the lateral to the dorsal position the swab in the oesophagus is removed and both oesophagoscopic and bronchoscopic aspirations are done in addition to a careful toilet of the pharynx and upper respiratory passages, as considerable secretion will have accumulated during the necessarily lengthy operation.

At the end of the operation the patient should be showing some normal reflexes He is returned to the ward with a B L B oxygen mask in position and should be nursed flat in an oxygen tent until consciousness has returned and the blood pressure readings are satisfactory Throughout the operation a slow blood drip transfusion is maintained

Thoraco-laparotomy

The best access is provided if the full classical lateral thoracotomy position is adopted and the compromise position with the patient lying tilted posteriorly on the assumption that this allows a wide abdominal field is undesirable and based on a faulty impression that it provides better access to the duodenal end of the stomach An oblique incision across the whole of the left rectus muscle and if need be of the right one crosses the right costal margin to meet the eighth rib which is then resected along its entire length this provides an ample exposure after the diaphragm has been split at right angles to the line of the original wound down to and including the oesophageal hiatus If the patient is in a posteriorly tilted position the rib resection tends to be inadequate and calls for the use of unnecessarily heavy rib retraction If the full incision is employed exposure is made without the need for retractors When the diaphragm has been divided freely it is an advantage to stitch temporarily its edges to the parietal muscles of the thoracic cage and of the abdominal wall the sutures are haemostatic their use increases the width of the wound and the temporary attachment of the right flap of the diaphragm steadies the muscle and prevents kinking and obstruction of the inferior vena cava (Allison)

Radical total gastrectomy

By this procedure (Allison 1949) the whole of the stomach a portion of the lower oesophagus the spleen the left half of the body of the pancreas and a wide lymphatic field are resected *en bloc* The arguments for the extent of resection are based on the general surgical principles involved in the excision of any organ harbouring a cancer and are accentuated by the fact that the stomach has the widest lymphatic drainage of any viscus The invasion of some of these lymphatics by tumour is almost constant as the diagnosis of gastric carcinoma is rarely made in an early stage in 1949 Allison reported that in all his resection operations for malignant cardio-oesophageal obstruction no case was presented without post-operative histological evidence of malignant deposits in the lymphatic glands Because of gross spread many cases will be beyond the hope of cure and then palliative resection, oesophago-gastrectomy or oesophago jejunostomy may be all that is possible

The oesophageal exposure The oesophagus lies in a tunnel between the pericardium and the aorta and is covered by mediastinal pleura loose areolar tissue and the ligamentum latum pulmonis These tissues are divided freely and the oesophagus elevated from its bed together with both the vagal nerves and held upwards by encircling tapes If the growth is invading surrounding tissue their removal is required and this may entail opening into the right pleura this has no adverse physiological effect if adequate lung inflation is maintained. Any such opening is closed temporarily by a moist saline pack when the oesophagus has been lifted forwards by an encircling linen tape The oesophagus is cleared well down to the oesophageal hiatus which may require excision if invaded by growth as is commonly the case

Mobilization of the spleen If the tumour is operable the dissection is carried behind the lesser sac so that the stomach can be lifted forward with its associated lymphatics The spleen is mobilized by dividing the peritoneum on its lateral surface starting through the lieno renal ligament and carrying the incision upwards to the left limit of the oesophageal

hiatus With the spleen held forwards and upwards, the tail of the pancreas is cleared from the posterior abdominal wall and is divided just before the inferior mesenteric vein enters the splenic vein The pancreas has a rich blood supply and many vessels require careful ligation The cut surface of the pancreas is closed by fine interrupted thread or silk sutures After the splenic artery has been ligated and divided close to its origin from the coeliac axis, the corresponding vein is tied slightly to the left of its junction with the inferior mesenteric vein We have twice seen hepatic infarcts at autopsy, the result of clot formation in a splenic vein stump that was left too long (Symmers, 1950)

Mobilization of the stomach Attention is now paid to the lesser curvature The tape around the oesophagus is pulled upon, and the right crus freely divided after division and ligation of the large vessels in it the lesser sac is opened by free division of the peritoneal ligaments and the dissection is carried as close to the liver as possible so that the lesser omentum will be resected The left gastric artery is secured and divided close to the coeliac axis after the hepatic artery has been defined and isolated

The great omentum is detached from its colon attachment, care being taken to work in the correct plane so that the colic vessels remain intact the omentum is detached as far as the pylorus and will be removed in one piece with the stomach

The pylorus is cleared and the duodenum, after isolation and ligation of the gastro-duodenal vessels, is crushed between two Schumacher's clamps and divided The duodenal stump is then closed The lesser omentum is dissected up to the porta hepatis and when the stomach is held away to the left, the portal vein, the hepatic artery and the common bile duct will be left with a minimum of areolar tissue around them The mass of tissue to be resected is then held upwards on to the upper edge of the wound in moist pads while the jejunal loop is prepared

Preparation of the jejunal loop A divided jejunal loop is preferred to an anastomosis of the oesophagus to the summit of an undivided jejunal loop, as the latter method is apt to be followed by regurgitation of duodenal contents into the oesophagus with the production of an agonizingly painful oesophagitis, which in one of my patients led to death five weeks after a successful gastric resection, even though an enteroanastomosis had been done between the two ends of the loop If the oesophagus has required a high division to ensure a wide enough excision above an upwards extension of the gastric growth, anastomosis to the summit of an undivided jejunal loop may be under undesirable tension

The jejunum is lifted well into the wound and its mesentery deliberately inspected the pattern of the jejunal vessels and the type of mesentery, short and stout, or long and lax, will determine the site for the division of the arterial arcades The division should go to the root of the mesentery where two or three primary radicals to the first arch can be divided, provided an adequate collateral circulation is available this can be estimated by following exactly the course of the blood flow that will be left once the mesentery and its vessels have been divided This stage of the operation must be done with the greatest deliberation and care and every effort made to avoid haematoma formation which may rapidly obscure the outlines of the vessels to be preserved A long jejunal loop must be fashioned so that it will lie without tension when drawn up into the posterior mediastinum The bowel is not divided until the necessary dissection, division, and ligation of the jejunal vessels have been completed The actual bowel section is best made between two light Schumacher clamps The proximal end of the divided jejunum is implanted later into the side of the divided jejunal loop lower down, and this is done without the use of clamps Throughout the whole of this stage of the operation a constant estimate of the viability of the jejunum must be made and the end of the isolated loop must be of good colour before it is passed as

fit for the oesophageal anastomosis occasionally a cuff of it requires excision if the colour is doubtful

Oesophageal jejunal anastomosis At this stage the anaesthetist may be asked to decrease a little the inflation of the left lung but it must not be allowed to develop areas of atelectasis it is better to have the inflated lung held away in a moist saline pad than to allow it to collapse for more than a few minutes

Through an opening in the transverse meso-colon the isolated jejunal loop is threaded upwards into the posterior mediastinum and care taken to see that it lies in its new bed without tension If the length is satisfactory it is withdrawn into the wound and its open end closed and inverted by two continuous layers of catgut (00) While it is outside the wound the stoma for anastomosis with the oesophagus is prepared and after it has been



FIG 24 1—Radiograph showing an end to summit oesophago jejunostomy after total gastrectomy Although condemned in the text thi peration is favoured by some surgeons

opened to a length corresponding with the size of the oesophageal lumen any bleeding vessels are picked up in mosquito artery forceps and ligated

With the mass of the stomach held upwards with a clamp below the proposed line of oesophageal section to prevent the regurgitation of septic stomach contents into the gullet the posterior wall of the oesophagus is incised Although a clamp above this line may prevent soiling from the oesophageal mucus it is better to rely on suction rather than to run the risk of damaging the oesophageal wall with one Two rows of interrupted linen thread sutures (00 size or 000 silk) which approximate the muscular layers and mucous membrane to the corresponding jejunal tissue complete the posterior wall of the anastomosis of the oesophagus After the jejunal loop has been approximated without tension the anterior wall of the oesophago-jejunostomy is completed after the oesophagus has been cut completely across and the stomach removed the mucosal surfaces should be sutured by interrupted thread or silk stitches the knots of which lie within the lumen of the gut The suture is passed from within outwards on the oesophageal side and then over to penetrate

the jejunal wall from without inwards and then tied (after R. H. Sweet). The anterior suture line is reinforced by a series of fine sutures uniting the muscle of the oesophagus to the sero-muscular layer of the jejunum

The jejunum is then lightly sutured to the parietal pleura to relieve any tendency to post-operative dragging on the suture line and to increase the line of potential adhesion A final inspection of the anastomosis ensures that the jejunal loop is viable and of good colour. If doubt is felt on this point it is better to re-make the anastomosis than risk a post-operative leak.

The jejunum is attached by a few interrupted sutures to the edges of the hole in the meso-colon and the diaphragm is closed by a layer of interrupted sutures, the jejunum being sutured loosely to the re-fashioned hiatus opening, which must not be too tight



FIG 24 2—Total gastrectomy specimen.

Removed from a man of 65 years who presented himself at the hospital with symptoms of severe dysphagia an extensive carcinoma of the stomach has invaded the cardio-oesophageal junction (specimen 18 cm) The spleen and part of the pancreas are to the right

Oesophago-duodenostomy Exceptionally the oesophagus can be anastomosed to the duodenum without tension such an anastomosis is best made with interrupted unabsorbable sutures without clamps being used on either the duodenum or oesophagus At least two layers are required

The lung is fully re-inflated and the abdomen and chest wall closed in the usual layers, a tube being left *in situ* for underwater sealed drainage for 24 to 48 hours

When the dressings have been placed in position the table should be placed in the anti-Trendelenburg angle before the patient is turned on to the back to avoid the risk of jejunal regurgitation into the oesophagus which is no longer protected by an efficient diaphragmatic pinch-cock mechanism The bronchoscope is then passed to ensure complete clearing of the tracheo-bronchial tree and the nose and pharynx are sucked and mopped dry

A radiograph will show whether the lung is fully re-expanded The tube is connected to a water-sealed bottle and if the patient is not returning to consciousness he is taken back to the ward with an oro-nasal mask in position through which oxygen is administered

Post-operative management In addition to the usual post-operative care of a thoracotomy special problems with regard to correct fluid and electrolyte balance require constant attention. Unless paralytic ileus develops an in-dwelling duodenal tube is unwise as it may lead to oesophageal infection Fluids by mouth in sips are encouraged 30–48 hours after operation the fluid requirements being met by intravenous infusions until that time Milk, tea coffee and soup are allowed for five days when the diet is added to in the shape of thin bread and butter lightly boiled eggs and jelly Normal solids are allowed on the tenth day

State of the patient after total gastrectomy

The nutritional and metabolic state of these patients continues to cause considerable anxiety and the problems have been studied by Brain (1951) The same problems are posed by patients after oesophagectomy and oesophago jejunostomy Appetite is slow to return and may never return to normal large meals cause discomfort and weight loss is the rule The most careful restrictions are necessary to prohibit large bulky meals frequent small meals of high calorie value are far better Diarrhoea is a common complication

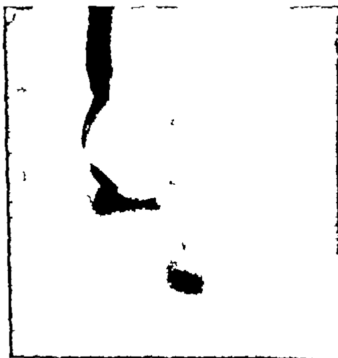


Fig 24 3 —Radiograph of a man of 50 years with a hiatus hernia.
A gastric ulcer is present in the thoracic pouch of stomach and another large one is sited on the lesser curve.

Brain believes that the post-operative difficulties may be caused by difficulty of ingestion due to *dyspepsia* or dysphagia, to defects in absorption disturbance of fluid balance and increased utilization of food Symptoms typical of the dumping syndrome noted occasionally after partial gastrectomy for peptic ulcer are seen comprising distension after food sweating palpitation, and a feeling of faintness Dysphagia may be due to oesophagitis from regurgitation of intestinal fluid or due to vitamin B deficiency with a typical associated glossitis this may be relieved by nicotinic acid and riboflavine and partly anticipated by including these in the post-operative diet Defects of absorption are represented by steatorrhoea which is constantly present this is best treated by doubling the quantity

of fat in the diet Brain advises a high fat diet (100–120 g fat daily in multiple small meals so that the fat is distributed between eight meals a day).

The surgical methods employed in the treatment of carcinoma of the oesophagus have been described in Chapter 19.

Thoraco-laparotomy for gastric ulcer and benign tumours of the fundus

The chronic gastric ulcer of the lesser curvature is best resected by the classical abdominal gastrectomy. occasionally the ulcer of the saddle-shaped variety impinges on the cardio-oesophageal junction and may require a thoraco-laparotomy approach The combined operation, however, is usually reserved for an adherent gastric ulcer in a portion of stomach herniated into the thorax In the radiograph (Fig 24 3) a gastric ulcer was present in a thoracic loculus of the stomach and a large ulcer, diverticular in appearance, is present high up on the lesser curvature this condition was treated by gastrectomy through a thoraco-laparotomy approach followed by oesophago-jejunostomy

A usua site for the rare large innocent tumour of the stomach of the nature of a fibro-myo-leiomyoma is the fundus · access to this tumour, which can be resected locally may be easier through the left leaf of the diaphragm than through the abdomen

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CHAPTER 25

THORACIC APPROACH TO THE SPLEEN

Trans-diaphragmatic splenectomy is not a surgical stunt It would be foolish to deny that removal of the spleen through an abdominal approach is a sound safe operation in most instances but abdominal splenectomy is a difficult and sometimes hazardous operation when the spleen is large vascular and adherent to the diaphragm Technically whatever the size and condition of the spleen a trans-diaphragmatic approach is simple and provides the easiest and most direct approach to the splenic artery and veins and for the severance of diaphragmatic adhesions As soon as the spleen has been exposed by the thoracic route it can be lifted well up into the wound and the securing of the pedicle is undoubtedly simpler than when the same manœuvre is being attempted at a distance in a somewhat far away space



Fig 25-1 —Enlarged collateral abdominal wall vessels in a patient with severe portal hypertension This natural anastomosis exceed in size the best artificial junction that could be performed between the splenic and renal veins.

The chief advantages of trans thoracic splenectomy lie however in the lessening of post-operative complications In a follow up of thirty five trans thoracic splenectomies there has been no example of subphrenic abscess of empyema or persistent left lower lobe atelectasis In twenty splenectomies collected at different hospitals subphrenic abscess developed in two and there were two thoracic empyemata After thoracic splenectomy there is no tension on the wound and the patient is early and comfortably out of bed which may be a factor in reducing the post-operative risk of venous thrombosis

In a book of this type it would be out of place to discuss the indications for splenectomy In the series of thirty five mentioned above the spleen had been removed by the trans thoracic approach for lacerations due to gun-shot wounds acholuric jaundice for splenomegaly in portal hypertension for purpura haemorrhagica for reticulo sarcoma and for

hydatid disease A few of the patients with portal hypertension have been subjected to anastomosis of the renal to the splenic vein, but this operation seems to have a doubtful place as the collateral circulation so produced is no greater than that of the normal anastomoses developed in this disease (see Fig 25 1) If venous anastomoses are of value in portal hypertension the use of the porto-caval venous shunt provides a greater hope of relief



FIG 25 2—A huge spleen partly covered by a gauze mop (note size in relation to surgeon's hand) been delivered through a trans-thoracic trans-diaphragmatic wound
Many adhesions to the diaphragm have been secured these would have provided formidable problems if tackled through abdominal incision The large vessels in the pedicle are seen in front of the surgeon's left hand.



FIG 25 3—A spleen greatly enlarged (20 cm) by a contained hydatid removed by trans diaphragmatic splenectomy

The operation For a moderately enlarged spleen the approach is made through the bed of the resected ninth rib and the diaphragm is widely incised along the line of this incision, the cut edges of the leaf being held apart as in the description given on page 78 (Fig 4 9) If the spleen is very large and h be difficult to deliver through a purely thoracic incision the costal margin is divi e thoraco-laparotom incision used for carcinoma of the stomach or of the cardi 1) This is usual

Any splenic adhesions to the diaphragm are divided and the spleen is then delivered into the wound and rotated to the right (Fig 23 2) The vessels in the gastro-splenic omentum are secured divided and ligated as far away from the stomach as possible The peritoneum behind and lateral to the spleen is divided freely to expose the splenic artery and the splenic vein in the fold of the lieno renal ligament these two vessels are secured by individual ligation and the attachments of the omentum to the lower pole of the organ divided and their vessels secured The tip of the pancreas is seen with great ease as the spleen is being held up and is quite secure from any accidental injury The diaphragm is closed by interrupted sutures and the chest closed with or without temporary drainage to a water sealed system. The management of any post-operative pleural effusion is along the usual lines

Right thoraco-abdominal approach for a porto-caval anastomosis in the treatment of portal hypertension

The incision first advocated by Satinsky (1948) gives a superb exposure of the structures that require exact dissection The ninth rib is resected in its entirety and the diaphragm split along the line of the incision With the patient lying on the left side the liver falls away and the inferior vena cava is readily exposed and dissected clear above the level of the renal vein the greatest hazard in its adequate clearing is the possible tearing of one of the thin walled lumbar veins the portal vein is seen lying anterior to it and the advantage of this exposure is that it is revealed directly as it lies behind the common bile duct Both the inferior vena cava and the portal vein are far more superficial in the wound than when a transperitoneal approach is employed. The portal vein is divided high up in the portal fissure the hepatic end being tied after a Blalock clamp has been placed on its proximal end. To allow blood to flow along a large part of the lumen of the inferior vena cava a part of the medial wall is pinched off in a Satinsky clamp an end to-side anastomosis of the portal vein is then made to the portion of vena cava held in the clamp exactly as in the Blalock operation of subclavian pulmonary artery anastomosis If the portal vein is of adequate length a side to-side anastomosis with the vena cava can be effected

It is not possible to judge the value of this operation at the present time

In the treatment of severe bleeding from oesophageal varices in portal hypertension as an emergency measure splenectomy alone still has a place as the patient may be altogether too ill to undergo a porto-caval anastomosis The division of the left gastric vein and the denuding of the peri-oesophageal tissues at the same operation may obliterate for a time the huge collateral supply to the varices Since the bleeding occurs so commonly in the fundal end of the stomach and may be partly caused by the action of gastric juice there is a place in an emergency for oesophago-jejunostomy the oesophagus is divided above its junction with the stomach and the opening into the stomach closed and infolded. A jejunal loop is then prepared (as in the operation of oesophago jejunostomy described on p 424) and anastomosed to the oesophagus Packing of the peri-oesophageal tissue to create fibrosing adhesions has also been employed but is of doubtful value though supported by Garlock (1947 1950 and 1951)

There are grounds for the scepticism of many as to the value of these operations employed for portal hypertension and the relief they afford may be of only a few years duration In one of my most successful operations for oesophageal varices no more bleeding followed what appeared to be a very satisfactory porto-caval anastomosis The child who was 5 at the time of operation died eight months later of severe liver failure (the result of the hepatic cirrhosis causing the portal hypertension) without any further bleeding after

the procedure At post-mortem examination the anastomosis was completely obliterated by fibrous tissue

It is, however, unreasonable to base opinions on the value of artificially created shunts between the systemic and portal systemic system on an inadequate experience Blakemore (1947) and Learmonth (1947) have published full accounts of the problems involved

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CHAPTER 26

DIAPHRAGMATIC HERNIA

The increasing frequency with which gastric herniation through a defective hiatal opening is being recognized removes the diagnosis of diaphragmatic hernia from the list of odd rare surgical curiosities The diagnosis and management of hiatal deficiency is a common surgical task far exceeding in importance other examples of diaphragmatic hernia It is largely an acquired condition though its frequency in infancy suggests a possibility that the muscular development of the right crus of the diaphragm may be faulty and even congenitally weak.* But other types of hernia are met with in surgical practice and Harrington s classification is a practical one

(A) Non Traumatic Hernia

1 *Congenital—at birth*
   (a) Through foramen of Bochdalek
   (b) Through the oesophageal hiatus
   (c) Through the foramen of Morgagni
   (d) Through a deficiency of the left leaf of the diaphragm posteriorly in the region of the aortic hiatus

2 *Acquired*
   (a) Through the oesophageal hiatus
   (b) Through areas where the anlagen of the diaphragm fuse
   (c) Through the sites of congenital hernia

(B) Traumatic

1 *Indirect* types that follow a crushing injury
   (a) At any point of the diaphragm
   (b) Through the oesophageal hiatus (usually with a sac) of the sliding type
   (c) Through the leaf of the diaphragm (usually without a sac)

2 *Direct*
   (a) The results of wounds by a missile or knife
   (b) (i) The result of necrosis from an abscess below the diaphragm
   (ii) The result of inflammatory necrosis in empyema as the result of long standing pressure of a drainage tube on the diaphragm (no sac)

Unusual types of hernia

These are largely the true congenital herniae with no sac in the thorax abdominal viscera being found in direct contact with the lung or pericardium They depend for their existence on faulty embryological development of the diaphragm are always liable to strangulation except in gross defects such as the absence of large portions of the muscle and are curable surgically unless they reach hospital in the advanced stages of intestinal strangulation.

* At the Children s Hospital Birmingham so-called congenital short oesophagus " has been seen three times in two children of the same family

Embryological considerations. The separation of the coelomic cavity into pleural, pericardial and peritoneal sacs is complete in the 20 mm embryo The diaphragm is developed from elements of the third and fourth cervical myotomes, of the septum transversum of the ventral mesentery, of the fusion of the dorsal mesentery with the pleuro-peritoneal membrane, and mesodermal elements which grow into it from the belly wall muscle masses The pleuro-peritoneal canal closes in the third month of intra-uterine life The failure of fusion may be extensive (Fig 26 2)

If the various elements fail to fuse, persistent openings often containing portions of bowel may be found, when such structures are in the chest they are not in a serous sac If the anlagen fuse incompletely, or weakly, the normal abdominal pressure may force bowel

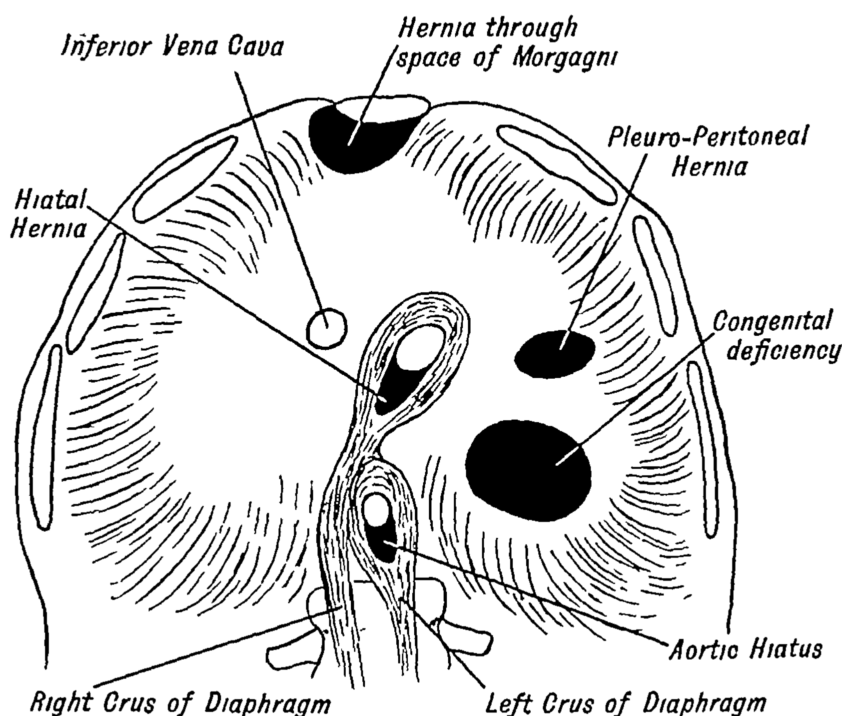


Fig 26 1 —Diagrammatic view of the under-surface of the diaphragm indicating the sites of herniae.

through them and such herniae will have true peritoneal sacs the fusion in such cases is deficient in mesodermal elements and the pleural and peritoneal elements alone will have joined to become a thin, insecure area This faulty development may explain localized areas of eventration of the diaphragm (see Fig 26 10). It is therefore not prudent to say that all true congenital herniae have no sac, though this will be so when the defect is complete enough to leave a " canal " Usually this is the condition found at operations for strangulated diaphragmatic hernia in childhood, apart from the large oesophageal hiatal deficiencies

Sites of congenital canal or weak areas (see Fig 26 1)

I { The foramen of Bochdalek
  { Persistent pleuro-peritoneal canal

II The retro-sternal hernia (foramen of Morgagni).

III Deficiencies of one dome.

Congenital hernia

Though occasionally diagnosed and treated in middle age, most of the patients with symptoms are met with in infancy and often die if surgical treatment is not immediate.

many not treated surgically die in the first year of life as the result of strangulated bowel in the foramen of Bochdalek or through an oesophageal hiatus

Symptoms Abdominal or thoracic symptoms may predominate In the abdominal group incessant vomiting with rapid resultant dehydration may suggest congenital hypertrophic pyloric stenosis or other intestinal tract obstructions Fortunately in the absence of a pyloric tumour a radiological examination will be carried out and a diaphragmatic hernia with characteristic features will be detected

Occasionally absent breath sounds in the chest usually on the left side may be associated with a tympanitic note on percussion and the stethoscope may detect peristaltic sounds such was the case in the patient whose radiographs are presented in Fig 26 4



(a) (b)

Fig 26-2 —Photograph of a post mortem on a man of 40 years There is a gross defect of the left diaphragm.

(a) The defect in the diaphragm seen from below

(b) The heart is seen deficient in pericardial covering to the left of the phrenic nerve and is in direct contact with the left lung there has been almost complete failure of pleural, pericardial and peritoneal fusion processes.

The abdomen in spite of obvious clinical intestinal obstruction may be scaphoid and free from distension

Thoracic symptoms are usually dyspnoea and cyanosis gravely accentuated by the attacks of vomiting The explanation of these symptoms lies in the atelectasis of the compressed lung and the gross cardiac and mediastinal displacement The pulse and respiration rate will be high and pyrexia will accompany infection of the collapsed lung

Treatment However young the infant surgical relief and repair of the hernia is indicated and many babies have survived operation, which is safer in the first 48 hours than a week later (Ladd and Gross 1941) The pre-operative measures include deflation of the stomach by an in-dwelling Ryle s tube correction of the dehydration by saline intravenous transfusions oxygen tent therapy and antibiotics such as penicillin

Operative treatment The anaesthesia should be by the intratracheal route and may consist of small doses of ether and nitrous oxide with abundant oxygen curare or muscle

relaxants are of help during the stage of reduction of the hernia and its repair The choice of incision is not always easy Undoubtedly the thoracic approach enables the diaphragmatic defect to be closed more efficiently if the defect is through the foramen of Bochdalek, but the manipulative return of the intestines and solid viscera, such as the spleen, may be less easy than through the abdomen The post-operative period always seems easier after a thoracic approach and a thoracotomy is usually best, except for the relief of the huge bilocular oesophageal hiatal hernia occasionally met with (see Fig 26 3), or for the hernia through the foramen of Morgagni Typical examples may be cited

Obstructed gastric herniation through oesophageal hiatus

P W , aged 10 months Since birth feeding had been difficult with many episodes of vomiting She was weaned at 5 months From that time the attacks of vomiting became more troublesome and repeated and there were frequent periods of severe constipation , at intervals the vomiting ceased completely for several days and the bowel habit became normal At the age of 10 months she was admitted to the Children's Hospital, Birmingham, in a serious condition of dehydration



(*a*) (*b*)

FIG 26 3

(*a*) A bilocular herniation of the stomach through the oesophageal hiatus in a child of 10 months symptoms of persistent vomiting

Invariably in these patients whether adult or infantile the highest part of the stomach in the right chest is formed by the greater curvature of the stomach, which has therefore undergone a volvulus with the lesser curvature as the axis

(*b*) Post-operative radiograph 5 months after reduction of the hernia and repair of the oesophageal hiatus

after two days of persistent vomiting The clinical condition was that of high intestinal obstruction without abdominal distension the child was undersized with a weight of 13 lb 5½ oz (6,645 grammes) Peristaltic sounds were present in the abdomen no obvious abdominal cause for the obstruction being found a radiograph of the chest was taken after a small barium meal and revealed a large bilocular hernia (see Fig 26 3 (*b*)) Since the hernia was clearly through a very large oesophageal hiatus and involved both sides of the mediastinum, an abdominal approach was chosen

At the operation the pylorus was seen just below the left lobe of the liver, the remainder of the

stomach being in the thorax which it had entered through a huge oesophageal hiatus The stomach was easily withdrawn into the abdomen after division of the left triangular ligament of the left lobe of the lung the peritoneal sac at the edge of the hiatus was freely divided a large part of the sliding hernial sac being left up in the chest By means of interrupted linen thread sutures (No 60) the defect in the right crus of the diaphragm was closed and the wall of the lower end of the oesophagus attached to the edges of the hiatus by a few further sutures

Recovery was satisfactory and the child has remained well and symptom free for the last three years (Fig 26 3 (a))

Strangulated diaphragmatic hernia through the foramen of Bochdalek (trans thoracic reduction and repair)

L. T aged 4½ months was admitted to the Children s Hospital Birmingham after continuous vomiting for two days the abdomen was distended and showed a typical ladder pattern of peri staltic waves The trachea and heart were grossly displaced to the right and loud peristaltic sounds were audible in the left chest A clinical diagnosis of strangulated diaphragmatic hernia was confirmed radiologically (Fig 26 4)



(a)



(b)

Fig 26-4

(a) Lateral radiograph of the chest and abdomen of an infant of 4½ months admitted with signs and symptoms of grave intestinal obstruction.

At operation the deficiency in the diaphragm was through the foramen of Bochdalek

(b) A year after operation.

The child is well and symptom-free The left leaf of the diaphragm remains paralysed as a result of the left phrenic nerve crush employed to increase the [illegible] of the abdomen to receive the distended loop of intestine seen at operation

Under intratracheal anaesthesia the left chest was opened plum coloured bowel was at once seen There was no sac present and the hernia was of the Bochdalek type With considerable difficulty the bowel which was just viable was returned to the abdomen after the left phrenic nerve had been crushed the left lung which was completely collapsed slowly re-expanded when the anaesthetic gas pressure was raised The defect in the diaphragm was closed and the chest closed without drainage The child made a good recovery and is well four years later though with a permanently paralysed diaphragm

Some difficulties in the treatment of strangulated or incarcerated diaphragmatic hernia in infants

The induction of anaesthesia may be dangerous because of the risk of regurgitant vomiting for this reason a tube should be passed down the oesophagus and gastric contents aspirated continuously during the induction which should be carried out with the patient in a propped-up position as soon as possible an intratracheal tube should be passed

Difficulty may be experienced in reducing the distended bowel into the abdomen, which has remained small when the mass of the intestinal tract has been in the thorax. Ladd and Gross (1941) have recommended a two-stage operation this consists of making an abdominal incision which is closed by skin suture only, so that the abdominal cavity is

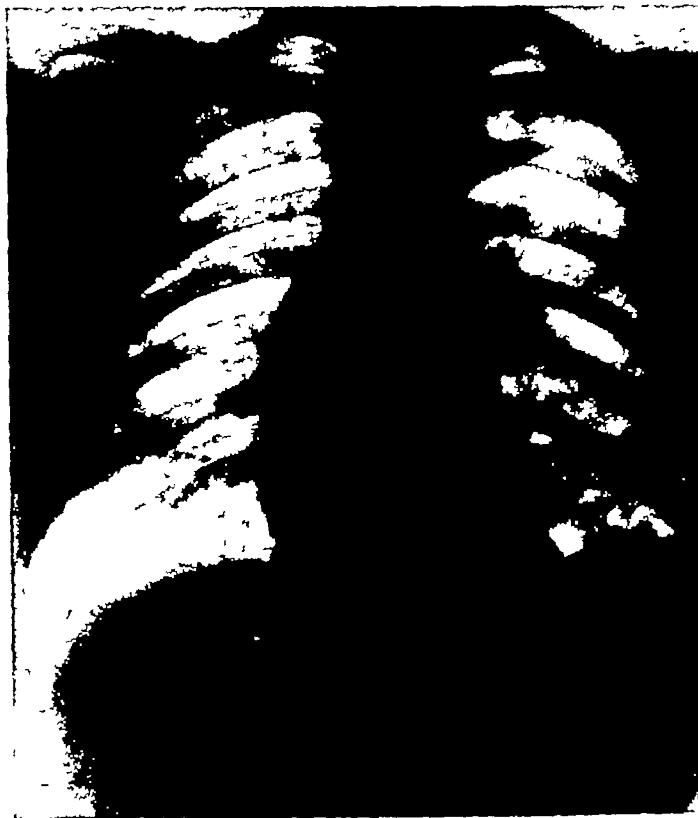


FIG 26 5 —Radiograph of a man of 35 years admitted with an obstructed diaphragmatic hernia (foramen of Bochdalek)
Repaired transthoracically

temporarily enlarged, at a later date this deliberately created incisional hernia is repaired In the post-operative care, lung re-inflation is encouraged by all means and this often entails the aspiration of air from the pleural cavity at the closure of operation and afterwards as indicated The infant should then receive oxygen in the immediate post-operative period. paralytic ileus and dehydration will be treated by continuous gastric suction and intravenous therapy

Strangulation of hernia through the foramen of Bochdalek

Obstruction or strangulation of this type of hernia may not follow until adult life Fig 26 5 is a radiograph of a man of 35 admitted with an obstructed left diaphragmatic hernia, the symptoms were those of high intestinal obstruction At operation there was

no sac in the left chest and the contents were those of small intestine loops which were returned through the foramen and the diaphragm replaced with uneventful recovery

Symptoms of congenital diaphragmatic hernia (excluding those through the oesophageal hiatus) in adult life

Although these herniae in infants and children are associated with a high mortality rate if not repaired surgically some patients survive to adult life or old age Exceptionally they remain asymptomatic and may be detected during the routine radiological examination of the chest when an air-containing viscous is seen On the right side a herniation of the liver may develop and be regarded as a mediastinal or lung tumour Probably most thoracic surgeons have had the humbling experience of carrying out a right thoracotomy



(a) (b)

Fig 26-6 —Herniation through the foramen of Morgagni before and after repair by the abdominal route (a) Pre-operative Note hernia to the right (b) After repair
Operation by M R P Scott Mason.

on the preliminary diagnosis of thoracic tumour and have been chagrined to find a herniation of the liver

The symptoms of the usual hernia of this type may include dyspepsia vomiting intestinal obstruction and cough with dyspnoea If the stomach is incarcerated haematemesis or melaena may develop as the result of congestion or from a surface erosion or true gastric ulcer (see Fig 24 3) This bleeding may be the cause of severe anaemia

Hernia through the foramen of Morgagni

This is extremely rare and I can only find one example in the Birmingham Children s Hospital This boy of 7 was under the care of Mr R P Scott Mason because of attacks of abdominal pain and vomiting The hernia seen in the right chest came through the foramen

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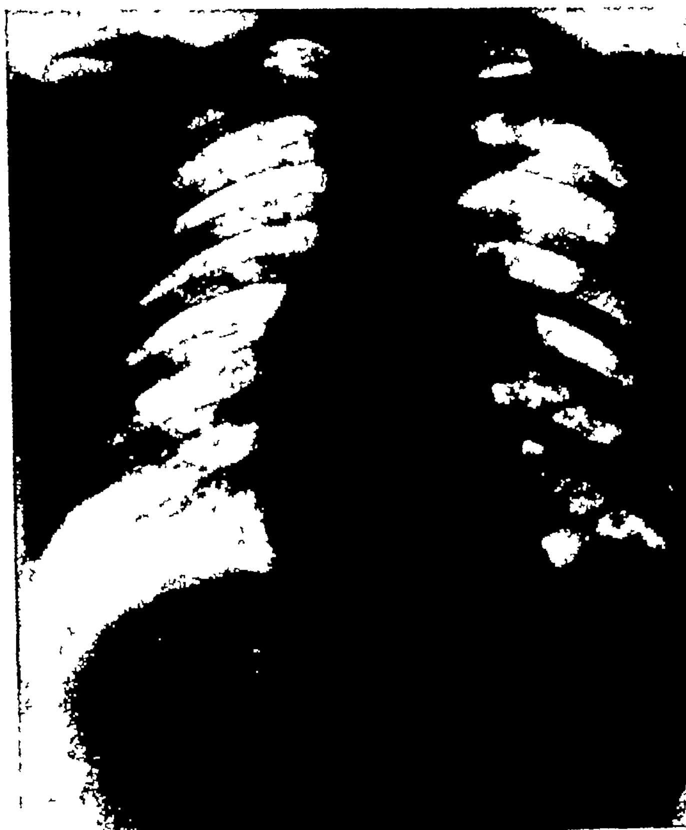


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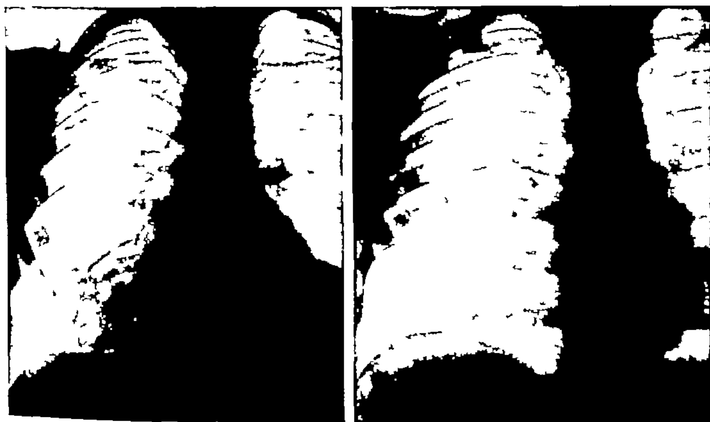
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of Morgagni, and was repaired by an abdominal approach. The child made a complete recovery (Fig 26 6). In an adult patient illustrated (Fig 26 7) there were no serious symptoms

Diaphragmatic hernia of traumatic origin

The diaphragm, usually its left leaf, may be torn by the compression effects of crushing injuries or wounded by the tangential passage of missiles or of a knife Such laceration may be detected during the operative treatment of thoraco-abdominal wounds, but not infrequently a hernia is present which may not cause symptoms until many years later, when



FIG. 26 7—An example of a hernia through the foramen of Morgagni in an *adult* The radiograph was taken 24 hours after a barium swallow and shows colon in the hernia

those of gastric or intestinal obstructions develop Patients wounded in the 1914–18 war are still being admitted occasionally with obstruction in such a hernia. The diagnosis is made on the history, the symptoms, the discovery sometimes of adventitious bowel sounds, or auscultation of the chest and by radiological appearances The repair and reduction of the hernia is usually not difficult through a thoracic approach which provides a good view for dividing any adhesions that might impede the return of the contents to the abdomen.

Eventration of the diaphragm

Apart from elevation and atrophy of the diaphragm after deliberate or accidental interruption of the phrenic nerve, a thin atrophied leaf may be present on the left side

The condition known as eventration is easily confused with diaphragmatic hernia as the symptoms and radiological appearances are similar the eventration may involve the whole leaf or only part of it (Figs 26 9 and 26 10) On radiological examination in a true eventration it is usually possible to follow the entire length of the line of the diaphragm without any loss or break in its continuity (Reed and Borden 1935) In differentiating the condition from a paralysis due to injury or disease of the phrenic nerve there is no true paradoxical movement though the movement is greatly impaired In half of these patients a barium meal shows the classical picture of inversion of the stomach with the greater curvature lying underneath the diaphragm

When symptoms are present they are frequently those of diaphragmatic hernia though less in severity yet associated with more pain in some patients for reasons difficult to cite



FIG 26·8 —Left-sided traumatic hernia which contained stomach and colon. The patient had been severely crushed in a car accident some months before this radiograph was taken.

They may be quite symptomless If symptoms are considerable relief can be obtained by a transthoracic plication of the atrophied leaflet At operation the deficiency rarely includes the whole diaphragmatic leaf Well-developed active muscle is found inserted into a very extensive thin aponeurotic central tendon the presence of this functioning muscle is an indication that the state is not due to faulty phrenic nerve innervation The plication must be done thoroughly and it is advantageous to use all the slack central part of the diaphragm and not to excise any of it As much slack tissue as possible is lifted up and the base of the fold so elevated is sutured together the flat is then folded down and sewn if possible to tendinous tissue as near to good muscle as possible Evans and Simpson (1950) have given interesting details of eight patients with this condition Seven of them had symptoms and four were operated on

Herniation through the oesophageal hiatus (hiatal deficiency)

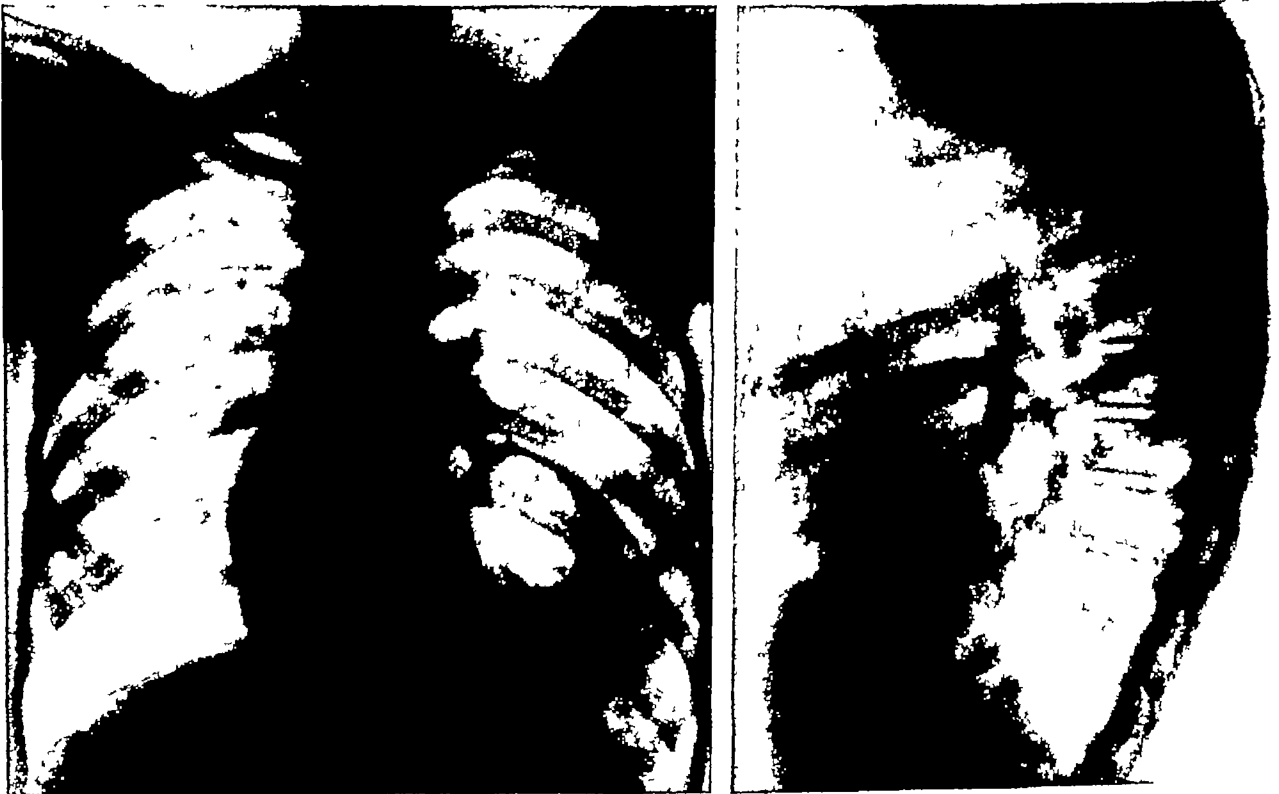
Anatomical and physiological considerations This condition represents the most important type of diaphragmatic herniation and requires fuller discussion than the conditions outlined in the previous section.



(a) (b)

FIG 26 9 (a) and (b) —Eventration of the left diaphragm in a woman of 48 years.

Symptoms of epigastric discomfort, dyspnoea and pain in the left lower chest sufficiently severe to justify operative plication of the diaphragm There was no paradoxical movement on radiological screening (Patient of Dr T V R Philip)



(a) (b)

FIG 26 10 —A localized eventration of the left diaphragm.

On a postero anterior view the condition had been regarded as a cyst of the lung The lateral view discloses a localized area of eventration and the intact line of the diaphragm is well seen There were no symptoms at all, the discovery being made by mass radiography (Patient of Dr D J Loughran)

During inspiration a sphincteric mechanism is necessary around the lower end of the oesophagus to prevent the upward regurgitation of gastric contents The muscular mechanism must be sufficiently powerful to prevent stomach regurgitation during violent changes of posture it is commonplace knowledge that though the human can swallow food in an upside-down position there is usually no regurgitation of stomach fluid in the same position The constant reflux of gastric fluid into the oesophagus is not only disagreeable but often causes serious changes in the walls of the lower gullet starting with a surface erosive oesophagitis that may progress to peptic ulceration and oesophageal stricture (see Chapter 19 and Fig 19 2) In the normal healthy individual gastric regurgitation is prevented by several factors of which the three most important are

1 The efficient closure of the muscular fibres of the right crus of the diaphragm during inspiration when the diaphragm contracts

2 The normal obliquity of the lower end of the oesophagus in its infra-diaphragmatic position as it passes into the stomach Allison (1951) has demonstrated how the looping fibres of the right crus of the diaphragm maintain this oblique position

3 The phreno-oesophageal ligaments (see p 409) These ligaments contain a large quantity of elastic fibrous tissue and become stretched when a hernia of the stomach develops into the posterior mediastinum Their importance as fixing agents is probably small

There is no true sphincter of the lower oesophagus itself either anatomically or physiologically and cardiospasm as described elsewhere (p 436) is a defect of muscular incoordination involving the lower third of the oesophagus in which relaxation of the circular fibres in the region of the cardia does not synchronize with the development of peristaltic waves higher up in the gullet Any factor whether pathological or operative that destroys the pinch-cock mechanism provided by the efficient contraction of the right crus or alters the natural obliquity of the lower end of the gullet and the tautness of the phreno-oesophageal ligament will set in progress the regurgitation of gastric contents into the oesophagus

If all follow up accounts of the operation of oesophago-gastrostomy in the treatment of lower gullet dysphagia were as thorough and as faithfully reported as those of Barrett and Franklin (1949) (see pages 439 424) the dangers inherent in a deficient hiatal muscular apparatus would be appreciated Erosion and ulceration followed later by stricture development is always a possibility when this hiatal efficiency is defective because of congenital or acquired herniation of stomach into the posterior mediastinum or following operation such as oesophagectomy for cancer in which the upper end of the oesophagus is anastomosed to the stomach In the technical management of cancer of the lower oesophagus the development of ulceration can be avoided by using an oesophago-jejunal anastomosis but in tumours of the upper oesophagus the risk of ulceration must be accepted as it is not always feasible to fashion a jejunal loop long enough to reach to or beyond the aortic arch

Herniation of the stomach into the posterior mediastinum is common and is met with in three different groups

(a) Hiatal deficiency in infants leading to
  (1) Obstruction or strangulation of the stomach and other parts of the alimentary canal (see Fig 26·3)
  (2) Severe attacks of vomiting haematemesis and melaena in infants often followed later by oesophageal stricture formation

(b) Hiatal deficiency in adults often middle aged women causing at first an unorthodox type of dyspepsia which may simulate cholecystitis gastric ulcer or coronary heart disease

Less commonly, but by no means rarely, a long period of dyspepsia may be followed by dysphagia, the result of oesophageal ulceration and stenosis (see Chapter 19)

(*c*) Hiatal deficiency in which part of the stomach herniates into the thorax, but without any displacement of the abdominal portion of the oesophagus, the entrance of which into the stomach retains its normal obliquity In this group the symptoms are usually those of distension and upper abdominal discomfort but without the sequelae of gastric reflux into the oesophagus This type of deficiency is often classified as a "para-oesophageal hernia" (see Fig 26 19)

(*a*) **Hiatal deficiency in infants and children** (see also Chapter 19)

This is *not a rare condition In 1949 and 1950 Astley, at the Children's Hospital,* Birmingham, confirmed radiologically that it was present in 32 patients 21 of these had *severe hiatal incompetence without real stricture formation, 6 of these were diagnosed in the first fourteen days of life and 14 between the age of one month to 18 months There were 6 with definite stricture formation (8 months to a year) and 5 had "short" oesophagus without stricture formation*

Much confusion still exists about "congenital" shortening of the oesophagus, haematemesis and melaena of the newborn, but the association between the two conditions is



FIG 26 11 —Radiograph (barium swallow) showing gastric hernia and spasm of oesophagus above it in an infant who died from vomiting and haematemesis
(See Fig 26 12 for autopsy specimen)

still frequently overlooked A number of infants have now been followed up at the Children's Hospital, Birmingham, who from early age had vomiting or haematemesis or melaena and who later developed a stricture and ulcer formation The true etiology of these conditions is the hiatal insufficiency which allows stomach contents to regurgitate into the oesophagus with the production of surface ulceration and is later followed by a steady rise of the oesophago-gastric junction and of part of the stomach itself, into the thorax The stricture, which is at first quite low down, may reach as high as the sixth thoracic vertebra and many

of these patients have been labelled as congenital short oesophagus or classed as the 'ascending fibrosis' of Brown Kelly the latter term is undoubtedly correct but the true cause of the fibrosing process is often overlooked A true congenital shortening of the oesophagus with a thoracic stomach is regarded by Astley as common but even if the congenital deficiency is one of shortening of the oesophagus the hiatal mechanism is lost because the gullet enters the stomach without any obliquity and the pinch-cock mechanism is absent

The importance of realizing the nature of the hiatal defect early in the disease would indicate that repair of the weakness at a very early age (the first few weeks of life) would not only alleviate the symptoms of vomiting and haematemesis but prevent the development



Fig 8·1 —Autopsy specimen from an infant who had suffered from vomiting and haematemesis since birth

Note the early herniation of the stomach beyond the diaphragm, the loss of obliquity of the oesophageal entrance into the stomach and the erosion and ulceration of the lower end of oesophagus just above the folds of herniated gastric mucosa.

of oesophagitis ulceration and stenosis which will produce a short oesophagus or the ascending fibrosis of Brown

Unfortunately this operation on infants has not been uniformly successful Allison s operation which has been successful in adult patients may fail in infants because it is often impossible to reduce the cardio-oesophageal junction into the abdomen as the oesophagus is truly short or too thickened by fibrosis even in the first few weeks of life

Gastrostomy as a means of treatment fails because the stomach contents regurgitate after each feed and the vomiting is usually increased not diminished The development of oesophageal ulceration occurring so early in life when gastric juice is largely free from hydrochloric acid indicates that some other factor in gastric secretion is responsible for the condition The ulcer seen in Fig 20 12 had the histological characteristics of peptic ulceration

Clinical features of hiatal deficiency in infancy The early onset of vomiting with or

without haematemesis and melaena is typical this may be severe enough to receive a diagnosis of hypertrophic pyloric stenosis or of duodenal stenosis but as mentioned elsewhere, in the absence of a palpable lump, surgical intervention for other unusual causes of alimentary canal obstruction will not be attempted without radiological investigation The diagnosis will be made if, at some stage, a radiological screening or photograph is taken with the infant in a prone position, for the gastric reflux and the raised position of the cardia will be discovered

In some infants the first indication of the condition may be the passage of a typical melaena stool the features of collapse and dehydration are often manifest quite early, depending on the degree of vomiting and the difficulty of getting any fluid into the stomach A few of these infants die with the indefinite diagnosis of "haematemesis and melaena of



(*a*) (*b*)

FIG 26 13 (*a*) and (*b*)—Radiograph of a child of 7 years with hiatal deficiency

There is a considerable loculus of the stomach above the diaphragm and the oesophagus has dilated above the area of oesophagitis oesophagitis was seen at oesophagoscopy but no true ulcer or stricture had developed

This was repaired by Allison's operation and the cardio oesophageal junction was replaced in the abdomen without difficulty the repair has remained satisfactory and all symptoms have disappeared

the newborn" With careful treatment, which requires the constant use of a propped-up position and careful feeding, many of these infants do well and by no means all develop ulceration though the hiatal deficiency persists

Treatment Some of these infants develop strictures, oesophagoscopic dilatation, combined with the constant adoption of a propped-up position, especially at night, the use of alkalis and great care in the feeding may produce considerable benefit at a later date major surgical procedures, as described below, may be essential

If surgical closure of the hiatal defect is to be effective it must be done before ulceration and ascending fibrosis have developed, but as already indicated the results to date have been disappointing The essential requisites for successful surgery are the reduction of the cardia below the diaphragm without tension, division of the peritoneal process that is in the thorax, rather in the nature of a false sac in front and to the sides of the oesophagus,

the re-suture of the divided phreno-oesophageal ligament to the under-surface of the diaphragm and the approximation by suture of the divaricated limbs of the right crus (see Fig 26 20)

In fully developed lesions the progressive or pre-existing congenital shortening and fibrosis of the oesophagus make these steps impossible and the cardia cannot be replaced in the abdomen

If the operation is delayed until the oesophagus has shortened and stricture formation has commenced the emphasis should be on conservative treatment and the inevitable development of a stricture accepted This stricture may require oesophagoscopic dilatation or later call for excision and oesophago jejunostomy the latter operation is not possible until at least the age of 8–14 years because jejunal loops of sufficient length cannot be fashioned in small children Belsey has overcome the difficulty in some young children affected by peptic ulceration of the oesophagus by performing oesophago-gastrectomy he resects the lesser curvature of the stomach with the object of reducing its acid pepsin secretion and so far has seen no example of ulceration above the line of anastomosis As described in Chapter 10 a few of these children with gross oesophagitis and stricture have been treated by oesophagectomy followed by oesophago-gastrostomy with the anastomosis placed high in the left thorax just under the aortic arch with satisfactory results

The treatment of oesophageal peptic ulceration and stricture formation has been described in Chapter 10 An attempt has been made here to indicate the grave consequences that may follow hiatal deficiency or congenital or acquired shortening of the oesophagus At the time of writing the surgical treatment of hiatal deficiency in infants remains unsatisfactory but the results of conservative methods are better than might be expected

(*b*) Hiatal deficiency in adults

The distension of the stomach by a meal in the subject with a normal oesophageal hiatus and a normally sited cardia raises the level of the stomach gas bubble in the fundus and thus further increases the obliquity of the gastro-oesophageal junction.

The area commonly called the cardia lies embedded in the mass of the crural muscles and there is no true abdominal portion of the oesophagus (Allison 1948) The contraction of these crural muscles during inspiration closes down the lumen of this part of the gullet and thus prevents the negative intrathoracic pressure sucking gastric contents up into it The key to this effective pinch-cock mechanism therefore lies in the obliquity of the oesophago-gastric junction and the effective contraction of the crural muscles If these muscles become ineffective the cardia tends to be sucked up into the thorax by the intrathoracic negative pressure and pushed up by abdominal distension In middle-aged obese women this happens frequently and produces a characteristic train of symptoms

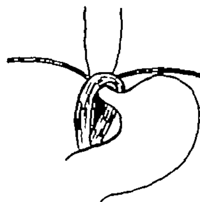


FIG *6·14 —Diagram of the right crural ring and its relationship to the cardio-oesophageal junction (after Allison)

Symptoms of hiatal deficiency in adults A typical history produces a complaint of dyspepsia associated with distension after food pain high up in the epigastrium and often in the back at the level of the eighth to twelfth thoracic vertebra an uncritical approach to such complaints might suggest a diagnosis of cholecystitis and some of the patients in our series have undergone cholecystectomy without relief even when gall stones have been

present Most of the patients with hiatal deficiency complain of heartburn and of regurgitation of bitter fluid into the oesophagus and occasionally into the mouth when they bend down to tie up shoe-laces some patients have had to abandon gardening because of the discomfort and heartburn caused by stooping Pain in the precordial area has been attributed in not a few to heart disease Alkalis usually fail to relieve the symptoms, a propped-up position in bed (usually on medical advice, after the correct diagnosis of hiatal deficiency has been made) often fails to provide relief this is not surprising because in real hiatal



FIG 26 15



FIG 26 16

FIG 26 15—Oesophageal hiatal insufficiency

This radiograph shows extreme regurgitation when the patient is recumbent, there is no true gastric herniation and the cardia is at the normal level as proved by oesophagoscopy and radiological estimate Symptoms were severe and were relieved by Allison s repair (see text)

FIG 26 16—A fully developed oesophageal hiatus hernia with a large loculus of stomach in the posterior mediastinum

This was repaired and the oesophago gastric junction was readily replaced in the abdomen with complete relief of symptoms

incompetence the use of this position does not prevent gastric contents from being sucked up into the gullet during inspiration

If oesophagitis develops, retro-sternal pain is often severe and erosions or ulceration of the oesophageal mucous membrane may cause an anaemia and occasionally haematemesis The diagnosis of many of the patients in the group has been peptic ulcer of the stomach or duodenum, cholecystitis, hyperacidity, cardiospasm or heart disease Many of these patients began their symptoms during pregnancy or developed them in the forties, when they began to put on weight

Diagnosis As the physical signs are indeterminate, the only one of value being the

occasional auscultation of peristaltic waves in the chest diagnosis will rest on the suspicion raised by a history of unorthodox upper abdominal dyspepsia associated with heartburn regurgitation and of pain in the areas mentioned and its confirmation by careful radiology The essential radiological appearances will be brought out by screening the patient in the recumbent position during a barium meal examination and noting the reflux of barium into the oesophagus while slight pressure is applied to the abdomen The examination will also reveal the presence of a gastric mucosal pattern above the level of the left leaf of the



Fig 26-17



Fig 26-18

Fig 26-17 —Large oesophageal hiatus hernia

This obvious herniation was only visible when the patient was placed in the recumbent position after barium had been swallowed to the stomach

Fig 26-18 —Oesophageal hiatus hernia in a woman of 60 years with severe symptoms of 15 years duration followed by the development of dysphagia.

At oesophagoscopy severe ulceration was present in the oesophagus

diaphragm The severity of symptoms depends on the degree of gastric reflux rather than on the size of the herniation of the stomach if the hiatal hernia is associated with a normally placed cardia the symptoms may be slight or absent and this is often noted in what is sometimes termed a para-oesophageal hernia (Fig 26 19)

Treatment of hiatal deficiency The selection of patients depends largely on the severity of the symptoms and the appearances of the oesophagus when studied through the oesophagoscope If all patients with hiatal deficiency were operated upon the demand for surgical beds would be high for the condition is an extremely common one far exceeding

that of cholecystitis Patients with milder symptoms are treated by dietetic measures, alkalis to relieve gastric acidity and the use of the propped-up position at night If heartburn and regurgitation are severe an oesophagoscopy should be carried out if this reveals a reddened oesophageal mucous membrane with areas of erosion or leucoplakia, operative repair is certainly indicated. Disabling dyspepsia and pain are further indications for surgery and the evaluation of the severity of the symptoms is not always easy Haematemesis and melaena are important pointers to the need for repair —Actual ulceration of the elevated portion of the stomach is not common though it undoubtedly develops in some patients In my own series two patients have had chronic peptic ulcers in the elevated areas of stomach and these were treated by gastrectomy followed by oesophago-jejunostomy

The operation The thoracic approach with the patient under intratracheal anaesthesia

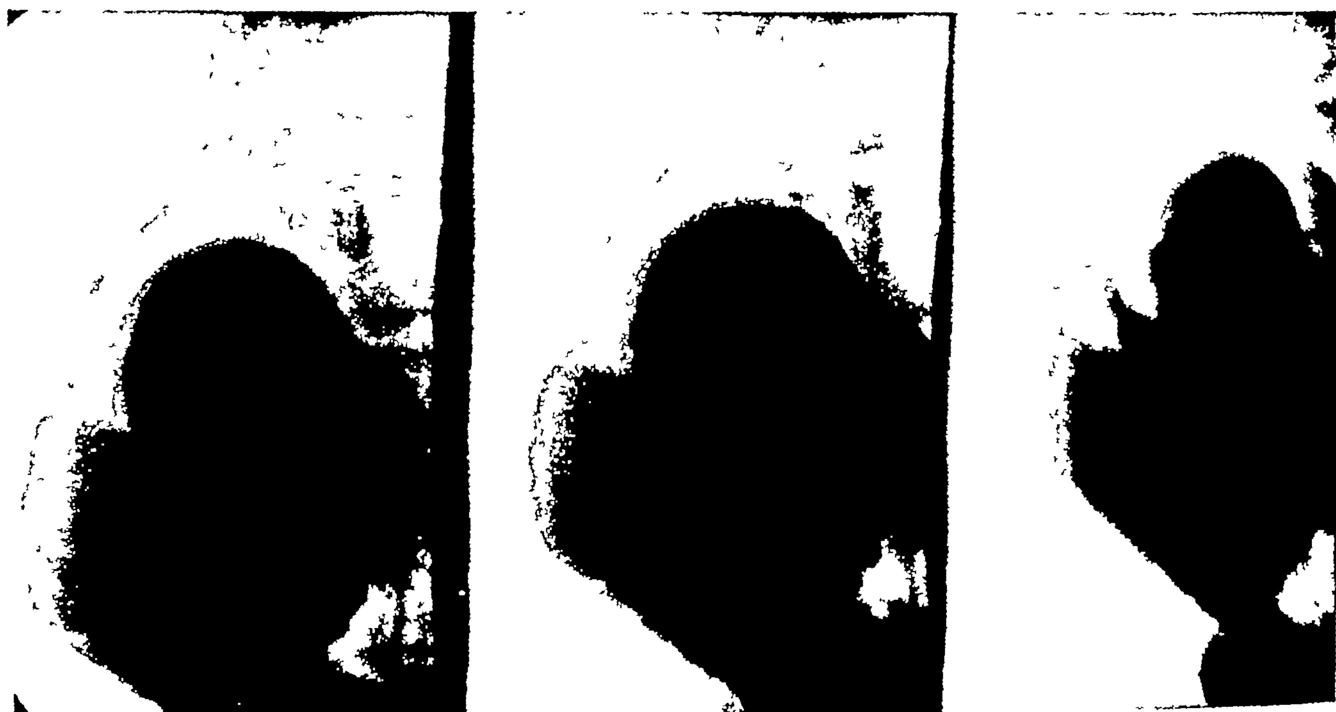


FIG 26 19 —The type of hiatal hernia often referred to as "para oesophageal"

In spite of a large hernia there were no symptoms of oesophagitis The picture on the right was taken after the patient had been in the Trendelenburg position for several minutes and no oesophageal regurgitation has taken place The oesophagus has a large curve and enters the stomach obliquely The symptoms were those of upper abdominal discomfort after meals but there was no heartburn

supplemented by curare is the ideal it provides a better approach than the abdominal one to the seat of weakness, namely the posterior wall of the oesophageal hiatus, and there are no obstructions in the way, such as the left lobe of the liver, and no need for a difficult dissection at the depths of a laparotomy incision Through a thoracic approach the oesophagus is lifted out of its bed, the hernial sac cut away and the oesophageal hiatus easily defined and cleared of its areolar and serous covering the reduction of the hernia and the repair of its wall is readily executed by the manœuvres practised by Allison under easy vision and without the need for any deeply placed retractors

The left chest is opened widely after the subperiosteal resection of the whole length of the eighth rib The lung which is kept well inflated throughout the operation is held away by pressure on a large moist swab the ligamentum latum pulmonis is divided and the oesophagus, after being thoroughly defined and cleared, is lifted upwards by means of an encircling linen tape The oesophageal hiatus is then cleared thoroughly by scissor

dissection of its serous coverings this dissection must be carried down posteriorly till the loop of the right crus is seen clearly to the full extent of its encirclement of the oesophagus the gap between the right and left components of the right crus will be obvious

A small incision is then made through the tendinous portion of the diaphragm A finger is passed up from below into the hiatus and it will emerge into the posterior mediastinum covered by peritoneum (the sac of the sliding gastric hernia) and the stretched phreno-oesophageal ligaments the sac is opened and freely divided along its whole periphery When this has been done a pair of Moynihan s cholecystectomy forceps is passed

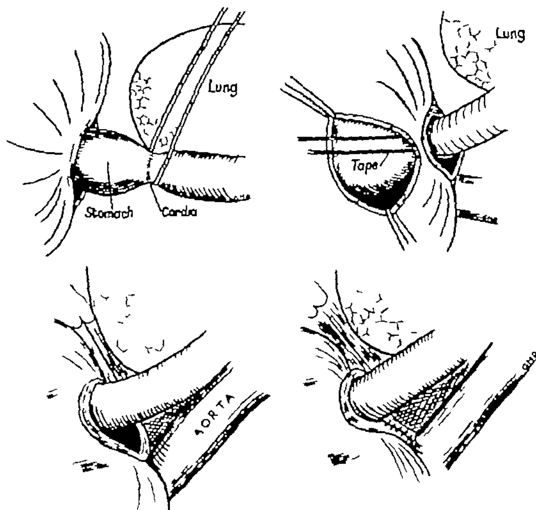


Fig 26-20 —Steps in the repair of hiatal hernia by Allison s method.
(a) The oesophagus has been lifted up by a tape
(b) and (c) Through a small incision in the diaphragm a finger has been passed into the sac which has been cut away the oesophagus is drawn down into the abdomen by traction on the previously placed tape and the hernia of the stomach reduced
(d) The gap in the posterior part of the right crural ring has been displayed and then closed with interrupted thread or silk sutures.

through the diaphragmatic incision through the hiatus and picks up the linen tape that has been passed around the oesophagus Traction on this tape reduces the lower end of the oesophagus well into the abdomen and at the same time lifts it up a little so that the posterior margins of the crural ring are seen clearly (Fig 26 20)

The cut edges of the peritoneal sac and the divided phreno-oesophageal ligament are then sutured to the peritoneum on the under-surface of the diaphragm to repair the ligament that anchors the stomach and which has been stretched by the herniation into the thorax

The important part of the operation follows this is the approximation of the divaricated muscle masses of the right crus by a few interrupted linen thread sutures these must

not be tied so tightly that atrophy of the muscle would follow, for the continued active contraction of an efficient right crus is necessary to prevent gastric regurgitation into the gullet The placing and tying of these sutures convert the V-shaped divarication into its normal Y shape The approximation of the fibres should be such that the tip of a little finger can be scarcely admitted between it and the oesophagus

The tape which has been holding the oesophagus down into the abdomen is then removed and the diaphragmatic wound repaired by interrupted thread sutures The chest is closed in the usual way, and the lung fully re-inflated In our series we have not used intrapleural drainage, any post-operative effusion being aspirated in no instance has pleural effusion, or lower lobe atelectasis, been a factor of any serious importance

Criticism of other methods of repair. The repair of the deficiency through an abdominal approach is technically more difficult than through the thorax, because of the necessity to pack off the stomach and intestines and the access to the posteriorly placed deficiency in the hiatal opening is more difficult, the descriptions of methods in which the hiatal opening is diminished in size by suture of the anterior edge of the hiatus to the ligaments in front of the vertebral column are puzzling because they fail to leave a pliable muscular pinch-cock mechanism in the crural ring The use of fascia lata tends to produce a rigid hiatus but has been extremely effective in the hands of Harrington who has a vast experience of diaphragmatic surgery

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CHAPTER 27

SUBPHRENIC ABSCESS

The surgical aim in the treatment of subphrenic abscess is to drain the pus without transgressing the main pleural and peritoneal sacs (extraserous drainage) Barnard (1908) showed conclusively that high mortality rates followed disregard of this principle and Harley (1949) has produced evidence recently which confirms the value of extraserous drainage Faxon s (1941) statement that inadvertent contamination of an uninvolved serous cavity during the drainage of a subphrenic abscess more than doubles the mortality rate indicates the need for a scrupulous selection of the site for drainage

Chemotherapy and antibiotic substances can probably sterilize an early subphrenic cellulitis but more usually they damp down the virulence of infection in these spaces and enable a patient to linger in chronic ill health for many months Chronic subphrenic abscess may be difficult to diagnose and is increasing in frequency because antibiotic therapy has lowered the death rate in the early stages The absence of notable fever and of leuco cytosis in the group is a peculiar feature often responsible for delay in or lack of accurate diagnosis The management of proved abscess is complicated by the considerable coincid ence of thoracic complications such as pleural effusion lung infection (abscess atelectasis or suppurative pneumonitis) and empyema and by a not infrequent involvement of more than one subphrenic compartment by the suppurative process

Etiology of subphrenic abscess Apart from trauma such as thoraco abdominal war wounds the focus of infection usually lies in the abdominal cavity with general peri tonitis secondary to acute appendicitis or perforated peptic ulcer as the most frequent source empyema development is a secondary feature due most commonly to faulty surgical technique in the drainage of the infra-diaphragmatic abscess but occasionally to an upward spread of infection or following a serous pleural effusion complicating the collapse of a lower lobe of the lung during the course of the abdominal illness Actual perforation of the diaphragm by a subphrenic abscess can occur and Harley (1949) recorded 15 examples of this in his collection of 182 cases Ochsner and de Bakey (1938) in reviewing 3 533 cases found that in only 2 5 per cent was the original infection in the thorax

Occasionally subphrenic abscesses develop in the absence of any detectable antecedent peritoneal infection and are possibly blood borne as in the instance of the staphylococcal perinephric abscess which notoriously follows some two to three weeks after a boil or carbuncle has been present elsewhere This type should be suspected in any obscure example of pyrexia of unknown origin for once considered its detection is often simple after clinical and radiological investigation. Harley described 17 such patients with a primary abscess in his large series and it is of interest to note that they represented the group with the lowest mortality rate (23 5 per cent)

Liver infection as a cause of subphrenic abscess A liver origin is present in about one-tenth of the patients except in tropical countries where the incidence may be con siderably higher because of the frequency of amoebic abscesses Since the war this fact is of importance for scattered throughout every chest clinic is the history of the ex-service man who has been under investigation for a chronic cough with expectoration. Fig 27 5 is the radiograph of the chest of an ex-soldier with a humped diaphragm and changes

in the right lower lobe who was referred as suffering from carcinoma of the lung because of haemoptysis He was treated twenty years previously for amoebic colitis Such a condition due to an amoebic abscess that has ruptured through the diaphragm into a bronchus will not be diagnosed if "typical" anchovy pus is expected, for the secondary infection so often present alters the naked-eye appearance and the greatest importance should be attached to a history of service in an amoebic area As described later, the diaphragm usually shows a characteristic shape and amoebae may be detected in the sputum In several instances the diagnosis has not been made until a pathological examination of an operation specimen after lobectomy has been performed for a chronic lung abscess or for bronchiectasis

Apart from this group of immediate post-war interest, subphrenic abscess may follow liver abscesses, the result of suppurative cholecystitis or suppurative pyelephlebitis The abscess is often a terminal complication to an illness characterized by high pyrexia, rigors and jaundice, and this type, as would be expected, causes a high mortality rate

Subphrenic abscess due to malignant disease in the abdomen Carcinoma of the stomach or pancreas is sometimes the cause of subphrenic abscess and this is more frequent on the left than right side, accounting for a higher mortality rate there than in the right-sided abscesses Harley described 50 left-sided abscesses in a series of 182, and in addition to these, 10 were bilateral abscesses, the mortality rate being 50 per cent on the left as compared with 31 per cent on the right side

Subphrenic abscess as a complication of mediastinitis or spinal osteomyelitis Acute osteitis of the vertebrae is a very unusual cause of subphrenic abscess and because of the obscure symptoms may be overlooked as a complication of mediastinitis it is usually a terminal event

The chronic "missed" abscess An unsuspected, undiagnosed subphrenic collection of pus often producing chronic ill-health, frequently with a profound anaemia often without leucocytosis, may exist for months Its presence may be declared by its natural proximity to the surface or by its rupturing through the diaphragm into the lung the latter egress may produce a confusing diagnostic picture which may receive the label of lung abscess, empyema, bronchiectasis or pulmonary tuberculosis Surgical treatment of the thoracic condition may provide the first suggestion that the origin of the suppuration is infra-diaphragmatic, for pus may be found oozing through a diaphragmatic perforation

Subphrenic abscess after wounds Wounds that traverse the pleural and peritoneal cavities may produce infective processes above or below the diaphragm of 126 thoraco-abdominal wounds 12 developed subphrenic abscess (Blackburn and d'Abreu, 1945) Half of these patients had coincident pleural empyema, and in two, lipiodol instilled into one abscess cavity found its way through the diaphragm into the other one, while in the remaining four, when the chest was opened for the drainage of an empyema, pus was seen welling up through a perforation in the diaphragm All of these patients except one survived, both the supra- and infra-diaphragmatic collections being drained when a double infection existed In addition to these twelve patients, seven others with right-sided liver wounds developed pleurobiliary fistulae followed in each instance by an empyema drainage of the empyema was followed by recovery in all with spontaneous closure of the liver fistula

Anatomical features of subphrenic abscess. The localization of abscesses in the sub-diaphragmatic compartments after abdominal infection is dependent on anatomical factors and the laws of physics These spaces are divided into right and left compartments, which are themselves designated as supra-hepatic or infra-hepatic (Harley, 1949) for practical purposes there are two intraperitoneal sacs on the right and three on the left, the

bare area of the liver forming the lower boundary of the one extraperitoneal space while the extra space on the left is the lesser peritoneal sac Academically another extra peritoneal space lies behind the bare area of the oesophagus and above the left supra renal body

The right supra hepatic space is closed posteriorly by the upper layers of the coronary and right triangular ligaments The lower layers of these ligaments form the upper border of the right infra hepatic space (Morrison s pouch) This simplification of the right supra hepatic spaces is anatomically correct and clinically helpful An appreciation of it enables a good appraisal to be made of the differences in signs and symptoms that accompany the development of abscesses in the right supra and infra hepatic compartments the thoracic symptoms predominating when infection involves the area above the liver

It is pertinent at this stage to enquire into the reasons for infection spreading into these two right-sided compartments as abscess formation here is more than twice as common as on the left side

In the course of a peritoneal infection the resultant effusion will gravitate to potential spaces such as those under discussion and into the pouch of Douglas and there is evidence that the pressure is more negative in the upper than lower abdomen especially during inspiration the localization of fluid collections will depend on the nursing posture adopted and on the suction action of the diaphragm and the intestinal movements if the gut becomes distended by gas as is the rule in paralytic ileus the fluid will be displaced along natural channels such as the paracolic gutter Just as air introduced accidentally or deliberately as in therapeutic pneumo-peritoneum reaches the subphrenic compartments so too will fluid, and once the surface tension between the liver and the diaphragm has been broken fluid will occupy the potential spaces The subsequent local response to inflammation will produce confining adhesions

The presence or absence of air in a subphrenic abscess depends on the nature of the organism which may be gas producing or on the presence of an air leaking intraperitoneal lesion. Air is present only in 30 per cent of subphrenic abscesses on radiological examination

The right-sided predominance is naturally explained by the greater frequency of foci of infection on that side of the abdomen the result of perforated appendicitis and the complications of diseases of the gall bladder and duodenum

Diagnosis of subphrenic abscess The gradation of symptoms and signs from an obvious classical onset some ten to twenty days after a recognized operated abdominal catastrophe such as appendicitis or a perforated peptic ulcer or following a procedure such as partial gastrectomy to a far from dramatic and insidious onset emphasizes the lack of a typical pattern Pyrexia and a leucocytosis so typical of the rapidly diagnosed abscess complicating an abdominal operation may be lacking in a truly chronic abscess patient who may be ambulant yet suffering from persistent malaise exhaustion anaemia and often a chronic cough

Three-quarters of the patients have thoracic and abdominal symptoms in addition to the general constitutional disturbances the remaining quarter may have abdominal symptoms only or solely thoracic ones Those with combined symptoms often have diminished chest and abdominal movements with a typical referred phrenic nerve pain in the shoulder in the early stages Pleural effusion and collapse of the lower lobe on the side of the abscess may pass on to empyema and lung abscess with the further complication of a bronchial fistula through which pus is inadequately expectorated often after a small haemoptysis A history which includes these complications after an abdominal illness or following a laparotomy will suggest the diagnosis but in a thoracic clinic a number of

patients are admitted with a drained empyema which has failed to improve because the underlying subphrenic abscess is still present (see Fig 27·7 (*a*)), and it may be said here that if empyema and subphrenic abscess are coincident both require separate drainage, for no reliance can be placed upon Nature's spontaneous effort to provide trans-diaphragmatic drainage whether the fistula be into the pleura or into a bronchus

In supra-hepatic abscesses both on the right and left side the thoracic symptoms predominate with serous effusion as an early complication of great diagnostic value, but abscess in the right sub-hepatic space or in the lesser sac will not usually give thoracic signs and symptoms, pyrexia, ill-health and leucocytosis often accompanying a detectable mass in the abdomen

Radiological diagnosis By no means infallible, radiological examination by screening and by postero-anterior and lateral films is the most important single examination leading



(*a*) (*b*)

Fig 27 1

(*a*) Right posterior subphrenic abscess with characteristic diaphragmatic rise

(*b*) Lateral view

Note "peaking of diaphragm"

to successful diagnosis As pleural effusion is common, penetrating films are essential and may give more valuable information than screening, which, however, should never be omitted Usually the diaphragm will be elevated, immobile and thickened The elevation may be localized or general but if a localized elevation is noted the characteristic hump always overlies the abscess (Hailey) Generalized immobility of a normal thin leaf is by no means diagnostic of a subphrenic inflammation, for this may be noted after many abdominal operations in the first few post-operative days and is very characteristic of amoebic hepatitis without suppuration But a thickened, immobile diaphragmatic leaf is very significant Associated thoracic changes due to pleural effusion and collapse of a lobe or segment are strong supporting evidence of a supra-hepatic abscess

Below the diaphragm the presence of gas is of great diagnostic assistance but is only present in some quarter of the patients it may well be overlooked on the postero-anterior

view and is more readily *detectable in the lateral picture It may be confused with the normal gastric air bubble on the left side*

In suspected left-sided *abscess a barium meal may help the abscess producing* displacement of the body of the stomach

Exploratory needle aspiration As a diagnostic measure this has little to commend it and in recent years has been condemned because of the grave risk of contaminating the pleural cavity The long maintained assumption that in a subphrenic abscess the rise of the diaphragm is soon followed by adhesive obliteration of the costo phrenic sulcus is quite untenable as any who have had the misfortune to open accidentally the pleural cavity well know Aspiration immediately before operation on the table is generally dangerous and should be confined to the exploration of a suspected serous pleural effusion as a diagnostic measure to establish the presence or absence of an empyema and possibly for



Fig 272—A well-defined and humped elevation of the left diaphragm due to a subphrenic abscess that was drained.

the injection of a prophylactic dose of an antibiotic If a careful clinical and radiological examination has indicated the presence and probable site of an abscess an exploratory operation not only lessens the risk of *contamination of the pleura* but is more likely to discover an abscess that the *needle may have failed to detect The main objection to* needling however is that the *natural tendency to incise down along the line of the needle* that has successfully encountered *pus will often lead to a transgression of the pleural cavity* for in spite of many ingenious *suggestions in the literature that the pleura if not obliterated* should be sutured such a *manœuvre is frankly quite unreliable*

Treatment *Although* a considerable number of infections in the subphrenic area probably subside *before* the suppurative phase under full antibiotic and chemotherapy treatments established suppuration should be treated by drainage The operative approach to these spaces *is* not easy except through a risky trans-diaphragmatic incision after resection of a rib posterolaterally for the evacuation of pus in the right supra hepatic

compartment It is unwise to rely on an adhesive obliteration of the costo-phrenic sinus, even when the diaphragm has been grossly elevated as a result of the abscess, and the dangers of empyema formation are considerable if the old routine approach is adopted. Moreover, all statistical enquiries (Faxon, 1941 ; Ochsner and de Bakey, 1938, Harley, 1949) prove that a transpleural drainage has always carried a higher mortality rate than an extraserous approach.

Harley (1949) has effectively demonstrated the dangers of draining a subphrenic abscess across the free pleural cavity or the general peritoneal cavity and has reiterated the teaching of Barnard He found that of 42 patients drained by the extraserous route only 4 (11 per cent) died, in contrast with 27 deaths (33 per cent) in 83 opened across the free pleural or general peritoneal spaces

The anterior route. Abscesses in the lesser sac and in Rutherford Morrison's sub-hepatic



(*a*) (*b*)

Fig 27 3

(*a*) Right anterior subphrenic abscess with fluid level
Complication of sutured perforated duodenal ulcer
(*b*) Lateral view of subphrenic abscess illustrated in Fig 27 3 (*a*).

space can be opened anteriorly without encroaching on the free general peritoneal space and rarely produce signal difficulty The best approach is by a high subcostal muscle cutting incision for the supra-hepatic abscess and by a paramedian incision for the peri-gastric abscess in the lesser sac

The posterior extraserous approach (the Ochsner operation) This exposure should replace any higher attempt at drainage by resection of the eighth, ninth or tenth rib The twelfth rib is resected sub-periosteally, the muscles attached to its lower end being divided: the fascia beneath the posterior layer of the rib periosteum is incised carefully and the upper part of the peri-renal fascia is exposed and displaced downwards The attachment of the diaphragm to the arcuate ligaments is carefully divided and that muscle is displaced upwards together with the lowest fold of the pleural recess. A considerable amount of blunt dissection behind the liver will be needed before the thickened walls of the abscess are encountered and opened, good illumination and the constant use of the sucker to

maintain a dry field are valuable the abscess is opened widely and a large bore tube left in its cavity This tube is securely anchored by fixing it to the skin by adhesive strapping fixed through a safety pin as in the method used for anchoring an open empyema drainage tube

In the post-operative course this tube must not be shortened until radiological studies carried out after the instillation of lipiodol have demonstrated clearly that the abscess walls have collapsed and that nothing more than a tube track remains premature shortening or removal of the tube before adequate drainage has been secured may lead to loculation or sequestration of the abscess cavity



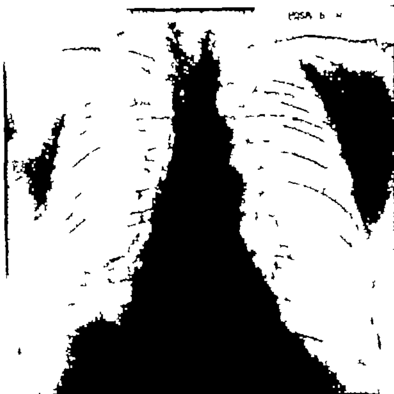


Fig 27·4 Fig 27 5

Fig 27 4 —Lipiodol sinogram after drainage of subphrenic abscess. The cavity still requires tube drainage

Fig 27 5 —Amoebic abscess of liver with rupture into right lower lobe with production of haemoptysis. Referred for examination suspect carcinoma of lung because of shadow in left chest demonstrated on screening to be aortic enlargement Proved case of amoebiasis which cleared under emetine Had first suffered from amoebic dysentery 20 years ago.

Appropriate chemotherapy is combined with post-operative breathing exercises and blood transfusion should be used if the haemoglobin falls below 70 per cent In the post operative period a constant watch must be maintained for the development of subdivisions of the abscess inadequate drainage extension of infection to other subphrenic spaces empyema development or atelectasis with possible septic pneumonitis or lung abscess formation

Treatment of thoracic complications

Pleural effusions Serous effusions are common their benign sympathetic nature can only be established or disproved by the use of the aspirating needle If the underlying abscess is satisfactorily drained the effusion will absorb rapidly If at the time of drainage of the subphrenic collection a thoracic paracentesis reveals a turbid fluid this

should be aspirated and penicillin instilled, the future management being along the lines of an infected pleural effusion (see Chapter 6) If a frank empyema is present and the indications for drainage are present, this is executed as if no subphrenic abscess were present, both collections of pus being drained separately through the appropriate anatomical site

Atelectasis The prompt recognition of this and its energetic treatment by postural drainage combined with chemo- or antibiotic therapy will often be followed by re-expansion if the subphrenic abscess has been adequately drained If the lobe does not re-expand after twelve hours then bronchoscopic aspiration under local anaesthesia should be done, as the cough mechanism may be too weak to clear the bronchi of the occluding mucopus Neglect to secure rapid re-expansion will leave the patient in danger of developing a lung

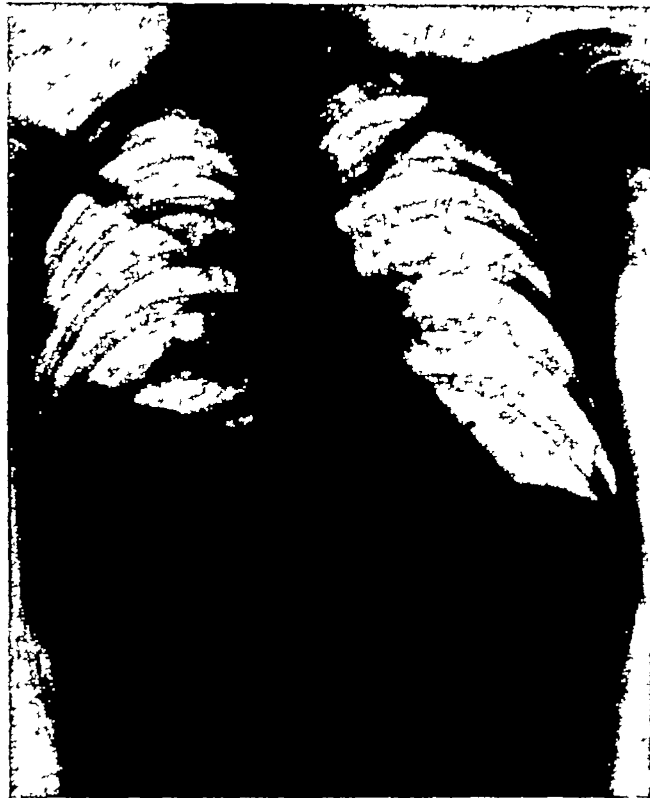


FIG 27 6—Radiograph of a patient twelve weeks after a pelvic abscess had been drained Constant pyrexia and cough The hump in the diaphragm indicates a typical subphrenic abscess There is also an inflammatory condition in the right lung

abscess, a pneumonitis or later bronchiectasis, neglect of this thoracic complication has undoubtedly been partly responsible for the high mortality rate of subphrenic abscess even after adequate surgical drainage If a lung abscess develops it is treated as outlined in Chapter 7

Treatment of subphrenic abscess due to hepatic amoebiasis Perhaps the greatest single diagnostic aid in recognizing this condition is knowledge of the fact that the patient lived for a time in an area where amoebiasis existed A history of dysentery, followed by a pyrexial illness, accompanied by cough with expectoration of purulent sputum should lead to an accurate diagnosis but amoebiasis is notoriously unfaithful to classical clinical patterns and the history of dysentery may be absent If the condition is diagnosed, however gross the thoracic signs and symptoms may be, surgery is withheld until a full course of anti-amoebic therapy has been instituted

Aspiration of an amoebic abscess should not be practised unless the routine course of treatment has failed and direct open drainage will only be instituted if the aspirated fluid reveals secondary infection by organisms usually of the coli typhoid group

Treatment of the late chronic inadequately drained abscess The relative infrequency of subphrenic abscess is undoubtedly the reason for its late recognition and imperfect treat ment and a small group of patients will be referred to thoracic clinics in an unsatisfactory clinical condition Some of these patients have undergone rib resection for an empyema that has followed a major abdominal operation and not infrequently the over riding thoracic symptoms conceal the exciting cause of such namely a subphrenic abscess usually in the supra hepatic compartment Pyrexia general ill health cough and thoracic pain lead to the clinical detection of a poorly moving chest wall with the underlying physical signs of a pleural effusion An associated collapse of the lower lobe may be overlooked The changes of the pleural effusion from a clear serous fluid to a purulent exudate is not uncommon and a rib resection for drainage of the empyema may follow without treatment being accorded to the subphrenic abscess or to the collapsed lower lobe the constitutional disturbance and the pyrexia will therefore continue In such a disheartening state of affairs the burdens of the ill patient may be increased by a despairing withdrawal of the chest drainage tube a chronic empyema being added to the inadequately drained areas of infection A fresh mind approaching this dismal sequel starts with the opportunity of grasping the essential features of a prolonged illness in such a history the greatest assistance will be provided by the elucidation of an initial abdominal cause to the train of events The following history is characteristic

B P a girl of 14 was operated on elsewhere on August 26th for an appendix abscess drain age was adopted as a course preferable to the removal of a gangrenous, adherent appendix situated retro-caecally Progress was never satisfactory a low pyrexia continued for three weeks and she remained toxic ill and apathetic The temperature continued to swing in spite of a long course of penicillin and sulphamethazine streptomycin was then given for a week with no effect Eleven days after the appendix abscess had been drained a radiograph demonstrated elevation of the right diaphragm and some right pleural effusion Three days later complaint was made of severe right-sided chest pain and on that day a resection of a portion of the ninth right rib was followed by the drainage of purulent fluid from the right pleural cavity

Closed drainage of this pleural effusion continued for two weeks until it was replaced by an open tube pyrexia persisted On November 1st a radiograph showed a collapse of the right lung covered by a thick visceral pleura and a fluid level at the bottom of the pleural cavity a resection of the tenth rib was carried out and open drainage re instituted She continued to deteriorate with no relief of pyrexia

She was admitted to the Hospital by transfer on November 25th three months after the original abdominal operation She was an ill toxic and dispirited child with a temperature of 102° The right chest was rigid and flattened and a little pus oozed from the two previous empyema drainage sites. The blood picture was R B C 3 900 000 Haemoglobin 86 per cent—11 9 gm per cent White blood cells 39 700 (in the differential count 84 7 per cent of these were poly morphonuclear leucocytes)

The clinical features of a right pyo-pneumothorax were confirmed by a radiograph which also showed a high right diaphragm The pre-operative diagnosis was right pyo pneumothorax and subphrenic abscess

On 30th November a right major thoracotomy was done through the bed of the resected fifth rib with an accompanying blood transfusion and under general intratracheal anaesthesia A large quantity of pus was evacuated and the imprisoned lung completely freed by an extensive decortication

The twelfth rib was resected and the abscess drained by Ochsner s method a large tube being left in the cavity The post-operative progress was rapid with immediate remission of the tem perature the lung re-expanded within 24 hours and the thoracic tube was removed a day later (see Fig 27 7 (*b*))



(a) (b)

Fig 27 7

(a) Radiograph of the chest of a child of 14 years three months after appendicectomy
There is a right pyo pneumothorax and a raised diaphragm

(b) Radiograph two days after decortication of completely collapsed right lung and drainage (extraserous posterior route) of subphrenic abscess
Operation by Mr Robert Brain



Fig 27 8 —An empyema and subphrenic abscess have been drained separately
The sinograms indicate need for continued drainage of empyema pocket but the tube in subphrenic abscess can be removed

The subphrenic abscess drained well but required tube drainage for four weeks. The patient was out of bed a week after the operation and was discharged 32 days after admission well and afebrile.

The essentials in treatment of an empyema coincidental with subphrenic abscess is that each cavity must be given separate drainage and that the empyema must be treated on its own merits

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